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THE EVOLUTION OF THE STARS AND THE FORMATION OF THE EARTH[1]

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Introduction

EVERY serious student of nature asks, sooner or later: What was the origin of the stars? What has been their history? And what does the future hold in store for them?

In harmony with our experience is the belief that all matter in the universe is endowed with the property of obeying certain fundamental laws, such as: every particle of matter attracts every other particle; a hotter body radiates its heat energy to a cooler body; gases expand indefinitely unless resisted by gravitation or other effective force. Again, everything in nature is growing older and changing in condition; slowly or rapidly, depending upon circumstances; the meteorological elements and gravitation are tearing down the high places of the Earth; the eroded materials are transported to the bottoms of valleys, lakes and seas; and these results beget further consequences. In general, the changes in small bodies proceed rapidly and in great bodies slowly.

Astronomers believe there has been an orderly development of the stars, in obedience to precisely the same simple laws that govern our every-day affairs. Starting with the materials as already existing, our problem is to trace in outline the probable course of the evolutionary processes which have given us the stellar universe.

The effort to find a solution brings us against two superlative difficulties:

First, save only the Earth and an occasional meteorite, all the bodies that concern us are at tremendous distances. We must study them at long range, through the reading and interpretation of the messages which their own rays of light and heat carry from them to us. We bring

[1] Second course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the Academy in the University of Chicago, on December 7 and 8, 1914.

bodies closer, in effect, by means of telescopes, but the reduced distances are still heroic. The stars, some of which are many millions of kilometers in diameter, are still seen as mere points of light in our most powerful telescopes, even though the telescopes magnify 3,000-fold.

Secondly, the evolutionary processes are exceedingly deliberate. We do not know that any *progressive* changes have ever been noted in any celestial body, except in the comets and meteorites, in the Earth's surface strata, and possibly in the so-called new stars. We observe changes in the clouds of Jupiter, changes in the surface features of the Sun, and some 4,000 stars are known to vary in brightness; but all these are short-period changes, and they do not indicate that progressive or permanent changes are involved.

We can get no help in our problem by waiting for any star to show signs of change in physical condition—we should probably have to wait tens of thousands, and perhaps millions, of years. We must take the heavenly bodies as they are, try to fit them into an orderly series representing the various stages of evolutionary development, and justify our arrangement by means of the evidence collected.

We need, first of all, to comprehend as thoroughly as possible what the individual heavenly bodies are, how they are arranged in space, and how they are related to each other, both physically and geometrically. At the cost of telling you many things you have already learned I shall recall a few features in the structure of the solar system and of the stellar system, and describe briefly the characteristics of each class of objects with which we have to deal.

The Solar System.

In the solar system we have the great central body, our Sun, around which revolve the 8 major planets and their 26 moons, the 800 minor planets or asteroids discovered to date, the zodiacal-light materials, the comets and the meteors. The Sun is one of the ordinary stars. It seems very large, very bright and very hot, because it is relatively near to us, and we receive from it our entire supply of energy; but, compared with the thousands of other stars visible on any clear night, it is merely an average star. Nevertheless, the Sun is a very large body; if it were a hollow shell of its present diameter we could pour more than a million Earths into it and still leave empty the space between the earth-balls. Traveling outward from the Sun we come, first, to the small planet Mercury, its diameter a little more than one third the Earth's diameter, which revolves once around the Sun in 88 days; secondly, to the planet Venus, just a shade smaller than the Earth, with period of revolution 225 days; and thirdly, to the Earth and its moon, which revolve around the Sun in one year. Fifty per cent. farther out than the Earth is Mars, its diameter a trifle more than one half the Earth's, with two tiny moons, and period of revolution 1.9 years. Next

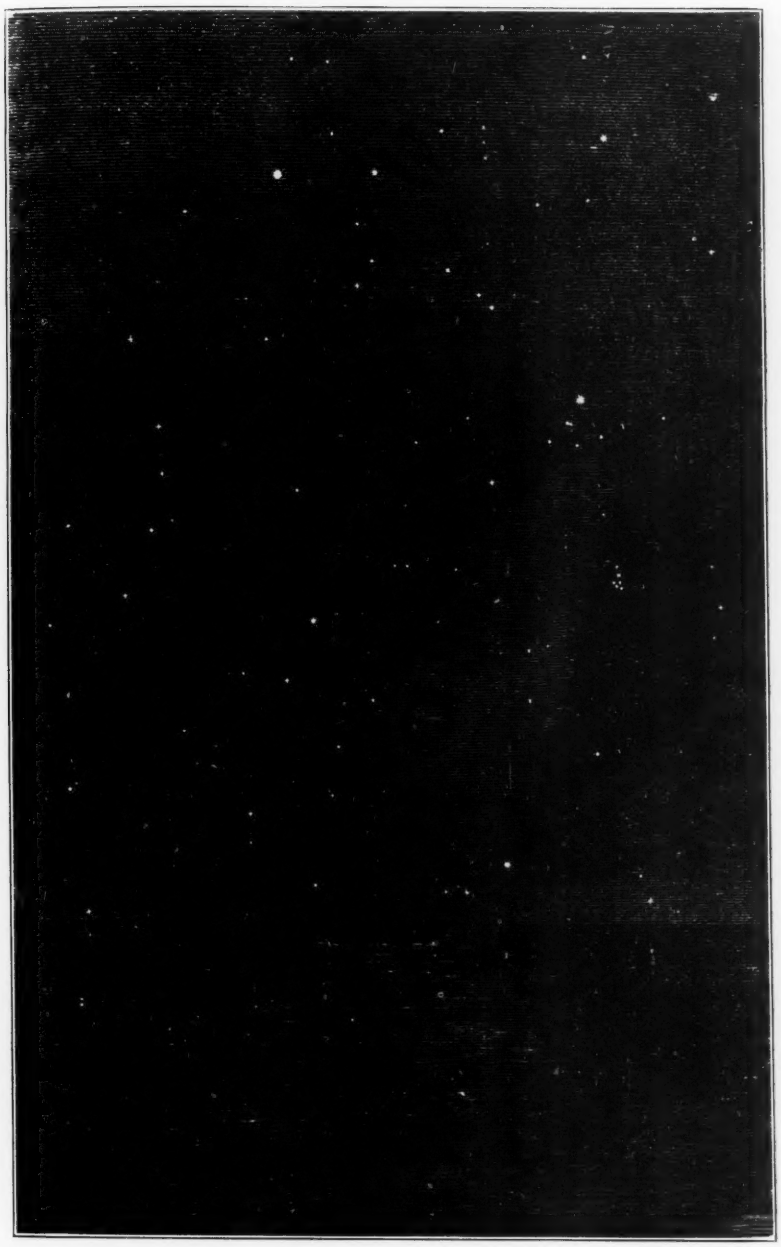


FIG. 1. THE ZODIACAL LIGHT.

are the asteroids, about 800 discovered to date, which revolve around the Sun, each in its own orbit, in from 1¾ to 8 years, the orbits varying greatly in size, eccentricity and position of orbit planes; then we come to the giant Jupiter, its diameter 11 times the Earth's diameter, and 9 moons, the system completing a revolution about the Sun in 12 years; still farther out is Saturn, its diameter 9 times the Earth's, with its wonderful ring system and 9 moons, all revolving around the Sun in 29½ years; next is Uranus, 4 times the Earth in diameter, with 4 moons, all revolving around the Sun once in 84 years; and finally we come to the outermost-known planet, Neptune, a shade larger than Uranus, and its one moon, this planet requiring 165 years to travel around the Sun.

Again, as to the material which composes the solar system: its distribution is most remarkable. Nearly all of it is in the Sun. If we add together the masses of the major planets, the hundreds of asteroids, the satellites, make liberal allowance for the comets, etc., and call the total 1, then the mass of the Sun on the same scale is 744; that is, of 745 parts of matter composing our Solar System, 744 parts are in the Sun and only 1 part is in the bodies revolving around it. To state it differently, 99⅞ per cent. is in the Sun, and only ⅛ of 1 per cent. is divided up to make the planets, satellites, asteroids, comets and meteors. The four outer planets, Jupiter, Saturn, Uranus and Neptune contain 225 times as much material as the four inner planets, Mercury, Venus, Earth and Mars. The Earth is fully 3,000 times as massive as the 800 asteroids combined. There is the zodiacal-light material, which, in a more or less finely-divided state, as dust grains or very small bodies, revolves around the Sun, each separate particle in effect a minute planet. This matter, distributed through a great volume of space somewhat the shape of a double-convex lens, whose center coincides with the Sun, and whose edge extends out at least as far as the Earth's orbit, reflects and scatters the Sun's rays falling upon it, and causes the illumination easily visible after sunset in the west and before sunrise in the east. Then there are the comets which pass in orbits usually very elongated around the Sun, their tails pointing approximately away from the Sun; and the meteoric matter, which, at least in part, and quite possibly all, revolves around the Sun in elliptic orbits. Occasionally a meteorite gets through our atmosphere to the Earth's surface, is found and is installed in a museum; but many millions which collide with our atmosphere every 24 hours are consumed by frictional heat in the atmosphere and lose their identity.

It is a most remarkable fact that all the planets revolve in orbits lying nearly in the same plane. Let us call the distance from the Sun to the Earth 1; then the distance from the Sun to Neptune is 30; and the diameter of Neptune's orbit is 60. Now our system lies so nearly in one plane that we could put it in a very flat band-box 60 units in diameter and only 1 unit thick, so that all the major planets and their

satellites, and all the asteroids with a very few exceptions, would perform their motions entirely within the box. The exceptional asteroids and the majority of the comets would dip out of the box because the planes in which their orbits lie make considerable angles with the central plane of the solar system.

It is an equally remarkable fact that the eight planets and the 800 asteroids are all revolving around the Sun in the same direction, which we call west to east. Likewise, the Sun rotates on its axis from west to east, and so also do Mercury, Venus, the Earth and its Moon, Mars, Jupiter and Saturn. Our moon, Mars's two moons, the seven inner moons of Jupiter, Saturn's rings and eight of its moons, revolve around their plants from west to east. From Jupiter out to Neptune we come upon exceptions to the rule. The eighth and ninth moons of Jupiter go around the planet from east to west. The ninth moon of Saturn is similarly reversed in direction. The four moons of Uranus move in a plane making an angle of 98° with the principal plane of the solar system; that is, nearly at right angles to the principal plane. The one moon of Neptune moves in a plane inclined 145° to the plane of the system; in effect, from the east toward the west. The equatorial planes of Uranus and Neptune are, without doubt, essentially coincident with their satellite planes.

The Stellar System.

Our solar system is very completely isolated from other systems. Light travels from our Sun out to Neptune in less than 4½ hours, yet it requires 4½ years to travel from our Sun to the nearest star, α Centauri. Stating the case differently, the nearest star is more than 9,000 times as far from our system as our farthest planet, Neptune, is from the Sun. We should have to go 7 light-years from our Sun in another direction to reach the second-nearest star. It is 9 light-years in a still different direction to Sirius. The average distances between neighboring stars, at least in our part of the universe, is 6 or 7 or 8 light-years. We can see that the stars themselves occupy very little space, and that they have an abundance of room to move about. Recalling, further, that the average speed of the stars is about 26 kilometers per second, which means that about 80,000 years would be required for the average star to travel over the average distance to its neighbor, we can see that collisions of two stars must be exceedingly rare; and that close approaches of two stars, approaches so close as to disturb each other violently, must also be rare. However, when we consider the number of stars in the stellar system, we should perhaps expect a few close approaches to occur in a human life time; possibly also a grazing collision, but probably no full collision.

The universe of stars—our stellar system—is believed by students of the subject, all but unanimously, to occupy a limited volume of space

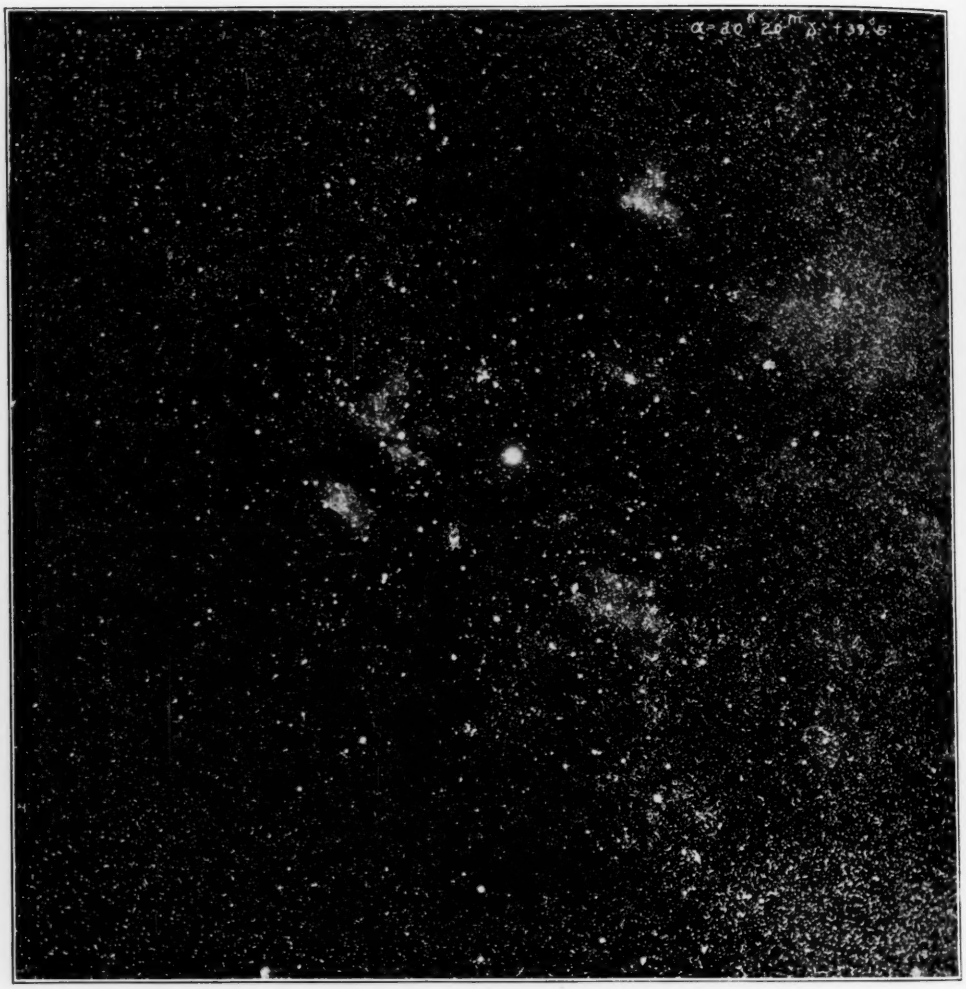


FIG. 2. MILKY WAY IN CONSTELLATION CYGNUS NEAR THE STAR GAMMA, photographed by Professor Barnard with the 10-inch Bruce camera of the Yerkes Observatory.

that is somewhat the shape of a very flat pocket-watch; more strictly, a much flattened ellipsoid or spheroid. However, it is not intended to convey the impression that the boundaries of the stellar system are sharply defined, or that the stars are uniformly distributed throughout the spheroid, and all at once, at the surface of the spheroid, cease to exist; but only that the stars are more or less irregularly distributed throughout a volume of space roughly spheroidal in form, and that the thinning out of stars near the confines of the system may be quite gradual and irregular. The equatorial plane of the spheroid is coincident with the central plane of the Milky Way. We see the Milky Way as a bright band encircling the sky, because in looking toward the Milky Way we are looking out through the greatest depth of stars. There is considerable uncertainty as to the dimensions of the system, chiefly for two reasons: first, the stars near the surface of the spheroid are everywhere too far away to let us measure their distances directly, and, in fact, so far away that we have not been able to measure their transverse motions—their proper motions—and thus to gain indirectly an idea of their distances; and secondly, the spheroid may be considerably larger than it seems because of possible, and even probable, absorption or obstruction of star-light in its passage through space. Newcomb has suggested that the shorter radius of the spheroid, at right angles to the plane of the Milky Way, may be taken as of the order of 3,000 light-years. The long radii of the spheroid, that is, the radii in the plane of the Milky Way, may be at least 10 times as great; that is, 30,000 light-years or more.

The solar system is believed to be somewhere near the center of the stellar system: the counts of stars in all parts of the sky indicate that the Milky Way structure is not much closer to us, so to speak, in one direction than in other directions; there are about as many stars on one side of a plane through the central line of the Milky Way as there are on the other. Wilhelm Struve's statistical studies of stellar distribution led him to conclude that the effective central line of the Milky Way is not a "great circle," but a "small circle," lying at a distance of 92° from the north pole of the galaxy and 88° from the south pole of the galaxy. Interpreted, this means that the solar system lies a short distance north of the central plane of the stellar system.

This conception of the stellar universe and Milky Way agrees in all important particulars with Immanuel Kant's ideas and description published in the year 1755—a remarkable contribution, based essentially on naked-eye observations, without the advantage of accurate observations laboriously made with telescopes. However, it was the star counts by the two Herschels, father and son, which put this conception of the stellar system upon the basis of confidence. Sir William Herschel, using an 18-inch reflecting telescope in the northern hemisphere, and Sir John Herschel, using the same telescope in the southern

hemisphere, counted the stars visible in the eyepiece, 15 minutes of arc in diameter, in 7,300 regions distributed rather uniformly over the entire sky. They found that the number of stars decreased rapidly as they passed from the central plane of the Milky Way toward the north and south poles of the galaxy. Here is a table deduced by Struve from the Herschels' counts.

Galactic Latitude Zones	Average Number of Stars Per Field 15′ in Diameter
+ 90° – + 75°	4.32
+ 75 – + 60	5.42
+ 60 – + 45	8.21
+ 45 – + 30	13.61
+ 30 – + 15	24.09
+ 15 – 0	53.43
0 – — 15	59.06
— 15 – — 30	26.29
— 30 – — 45	13.49
— 45 – — 60	9.08
— 60 – — 75	6.62
— 75 – — 90	6.05

The average number of stars in the Milky Way zone 30° wide, that is, in galactic latitude + 15 to — 15, visible in the eyepiece of the telescope, was 56, whereas in the region surrounding the north and south galactic poles the average number visible in the same eyepiece was but 5. The great condensation in the Milky Way is not fully evident from the table. The stars are much more numerous near the *central line* of the Milky Way than they are near its borders. The average number along the central line, found by Sir William Herschel, was 122. There is no reason to doubt that the preponderance of stars visible in the direction of the Milky Way is due to the greater extension of the stellar system in that direction than in the direction of the galactic poles.

It has been noted by several observers that the faintest stars visible in telescopes of moderate size, that is, stars of the 14th, 15th and 16th magnitudes, are plentiful in the Milky Way and very scarce at a distance from the Milky Way. The contrast between Milky Way and non-Milky Way regions is scarcely noticeable in the naked eye stars, but it becomes stronger and stronger as we pass to the fainter stars.[2]

If there is an absorption of light in its passage through space, such that the very distant stars are appreciably reduced in brightness, then the stars of average size and physical condition must be invisible to us when they are farther away than a certain limiting distance, and in that case the extent of the universe in the direction of the Milky Way

[2] A recent study of Mr. Franklin Adams's excellent photographs of the sky, by Messrs. Chapman and Melotte, shows a considerably smaller disparity in the numbers of faint stars in the galactic and non-galactic regions than the Herschels and others found.

may be vastly greater than we have described it; but this consideration would not act to increase the radius of the actual stellar system in the direction of the poles of the galaxy by any appreciable amount.

Investigations conducted principally at the Harvard and Greenwich Observatories indicate that the number of stars visible in our largest telescopes is of the order of 60,000,000 or 70,000,000, and that the number which can be recorded on photographic plates by means of long exposures with our largest reflecting telescopes is several times as great.

Investigations by Newcomb and Kelvin upon the gravitational power of the stellar universe to produce the observed velocities of the stars give indications that the visible stars contain in reality only a fraction, perhaps one fifth, of the gravitating materials concerned, and they conclude that more material exists in dark and invisible stars than in the visible ones. I am inclined to regard their estimates of dark material as of questionable accuracy, on account of the purely arbitrary assumptions involved.

Stellar Motions

It is necessary that we consider briefly the motions of the stars, including that of our own star. It has been found that all celestial bodies, as far as they have been studied, are in motion with reference to the entire system, and with reference to each other. Our Sun is no exception to the rule: it is traveling rapidly through the stellar system, carrying its planets and their satellites along with it. The apparent motions of the individual stars are not in general their real motions: they are a compound of the real motions and of our motion. If the other stars were really at rest in the great system, they would still seem to be moving because our star is carrying us past them, so to speak: the nearer stars would seem to be moving rapidly, and the more distant stars less rapidly, away from that point in the sky which we are approaching. Since the stars are really moving in a great variety of directions, with a great variety of speeds, their apparent motions are also in a great variety of directions, but the prevailing tendency of their motions is away from our goal.

By studying these compounded motions, Herschel, in 1783, and a long line of distinguished investigators following Herschel, have established that our solar system is traveling toward a point in distant space about on the boundary line between the constellations Hercules and Lyra. If the solar system is moving rapidly toward that point, the stars in that vicinity should, on the average, seem to be approaching us, and the stars in the opposite region of the sky should, on the average, seem to be receding from us. The spectrograph enables us to measure the rates of approach and recession of the individual stars. It has been found that while the hundreds of bright stars in the Hercules-Lyra region are traveling, some away from us and some toward us, with

a very great variety of speeds, yet, on the average, that group of stars seems to be approaching us at the rate of 19 kilometers per second. In a similar manner it has been found that the stars near the opposite point of the sky, while moving individually with a great variety of velocities of approach and recession, are, on the average, receding from the solar system with a speed of 19 kilometers per second. No one questions the explanation of these facts: the solar system is traveling toward the Hercules-Lyra region with a speed of 19 kilometers per second. If, now, the speed of 19 kilometers per second be maintained, and the longer radii of our stellar system be 30,000 light years, we should require a period of 450,000,000 years to travel from the center to the circumference of our system. The youth of the solar system was probably spent in a very different part of the stellar system from where it now is.

Comets

Are the comets bona fide members of the solar system as the planets are, or are they transient visitors from the greater stellar system? Immanuel Kant in 1755 advocated the view that the comets are genuine members of the solar system. From 40 to 70 years later Laplace advocated the other view, that the comets belong to the great stellar system, and that a few of them happen, in the course of their travels, to encounter the solar system. The latter view prevailed from Laplace's time almost up to to-day. If the comets are of our solar system they should move in elliptic orbits; that is, they should return again and again to the vicinity of the Sun.

If the Sun were at rest with reference to the stellar system and the comets should start with exceedingly small velocities from a very great distance, say 20 or more light years away, they would travel around our Sun in curves which we could not distinguish from parabolas. Interpreted, this means that they would eventually go back to approximately the same distant region of space from which they started and never again return to the solar system. If the comets should start toward us, from interstellar space, with appreciable velocities, they would move around the Sun in hyperbolic orbits, curves whose branches, one coming in toward the Sun and one going out from the Sun, diverge widely; such comets would go away to a region of space totally different from that which they had occupied before their solar visits and never return either to us or to their original habitation. Since the Sun is not at rest in the stellar system, but is traveling 19 kilometers per second toward the Lyra-Hercules constellations, it can be shown that the forms of the orbits of comets coming from interstellar space, whether they start from rest or with the average speed of the stars, would, in general, be strongly hyperbolic. The observed facts are that of the more than 400 cometary orbits determined, only 8 or 9 have been suspected to be hyperbolic. Further, the recent researches of Fabry and Ström-

gren have shown that all of the suspected cases either rest upon insufficient observations of the comets at the time of their appearance, so that the orbits are uncertain, or that the disturbing attractions of our planets have converted the orbits from the elliptic to the hyperbolic form after the comets have got well within our planetary system. Another fact is equally important. By virtue of our rapid travels toward the Lyra-Hercules region we should meet more comets coming from that direction than there are comets overtaking us from the opposite direction. To state this point differently: of the comets which swing around the Sun, a greater number should have come into our system from the Lyra-Hercules region than from any other region, and especially from the region of sky which we are leaving behind. The facts are otherwise: we can not say that the approaches of comets favor any particular direction.

The orbits of the great majority of comets are very close to the parabolic form. The nature of comets is such that they are under observation for a few weeks or a few months, and only an occasional one for a year or more. When but a small section of the orbit has been thus observed it is difficult to decide between the parabola and a very elongated ellipse. It happens, however, when these comets have been accurately observed through many months, and the disturbing attractions of our planets have been taken into account, that the orbits are found to be very long ellipses and not parabolas; some of the ellipses are so elongated that thousands, and occasionally hundreds of thousands of years, are required to complete one circuit of the Sun. Let us assume that a comet belonging to the solar system starts at rest, with reference to the solar system, from a point midway between α Centauri and our Sun, and travels around our Sun. It would be 60,000,000 years in reaching us, or 120,000,000 years in completing its circuit. It is evident that an immense amount of cometary material must exist in the outer regions of our Sun's gravitational field in order that a minute part of it may visit the Sun every three months, which is about the average interval of time between the coming of these bodies.

It should be noted that the planes of the very elongated comet orbits show no preference for small angles with the plane of the solar system: they intersect the solar system plane at all angles, and these comets come into our system from all directions indifferently.

We must hold, I think, that the comets are genuine members of our solar system; the great majority spend most of their time in the outer parts of our system, far beyond the orbits of Neptune, but they are moving through space as companions to our Sun as truly as the Earth and Jupiter are.

Aside from the comets which come from great distances, there are, of course, the so-called periodic comets which move in relatively short ellipses, revolving around the Sun in a few years, and reappearing at

predicted times and places. About 60 such comets have been observed with periods less than 100 years. There is the great Jupiter family of comets, about 30 in the family, so-called because their aphelions—the points of the orbits farthest from the Sun—lie near Jupiter's orbit. Their periods vary from 3 to 8 years, their motions around the Sun are all from west to east, as in the case of the planets, and their orbit planes make small angles with the plane of the solar system. In a similar way there are two Saturn comets, three Uranus comets, and six Neptune comets, one of the latter being Halley's. Halley's comet is revolving around the Sun from east to west; that is, in a retrograde direction; and the motions of two comets which disappeared many years ago were likewise from east to west. The motions of all the other short-period comets are from west to east.

The origin of the periodic comets is an interesting question. Newton, of Yale, who was the chief student of the subject, gave practical certainty to the view that the periodic comets have been captured, so to speak, by the major planets, and especially by Jupiter; that is, that comets approaching the Sun in their elongated orbits and passing close to the major planets have had their orbits converted, either during one visit or cumulatively during several visits, into the forms we now observe. Perhaps the strongest doubt as to the sufficiency of the explanation arises from the fact that 95 per cent. of the motions appear to be from west to east. Newton's theory seems to demand that about 25 per cent. of Jupiter's comets should move in retrograde orbits, whereas none of Jupiter's comets, nor the two Saturn comets, do so move. Three of the eleven comets related to Uranus and Neptune, namely, Halley's comet and two lost comets, travel in the retrograde direction. The capture theory is technical and we must not pursue it. Fortunately, there is another avenue of approach. Barnard has noted that the short-period comets differ in appearance from those which come to our system unexpectedly, in that the former are the more diffuse in appearance; that is, they have larger diameters in proportion to their total brightness. There is reason to believe that the head of a comet consists principally of separate small bodies. Now in a collection of small bodies the gravitational forces holding them together are extremely slight. When the group approaches the center of the solar system the Sun's attractions upon the nearer members of the group are appreciably stronger than upon the members which are farthest from the Sun. The orbital motions of the nearer particles are relatively quickened and those of the farther particles relatively delayed. If the comet is traveling upon a very elongated orbit the mutual attractions within the head can again be effective while the comet is in the outer parts of the orbit, and a condensing process probably occurs; but, if the orbit extends out only as far as Jupiter or other major planets, there is little opportunity for the internal attractions to re-condense the particles, and

the next approach to the Sun carries the scattering process a step further. Repeated returns to the Sun dissipate the individual constituents of the comet more widely. The intensity of the comet's light is reduced, and eventually it becomes too faint for discovery and observation. There is little room to doubt that this process is responsible for the total disappearance of several periodic comets.

Meteor Streams

The argument is strongly supported by the meteor streams. It is well known that on certain nights of the year we see an unusually large number of meteors, which come from certain definite directions in space. These meteors have been extensively observed and their orbits have been computed. The illustration shows the orbits of four such swarms.

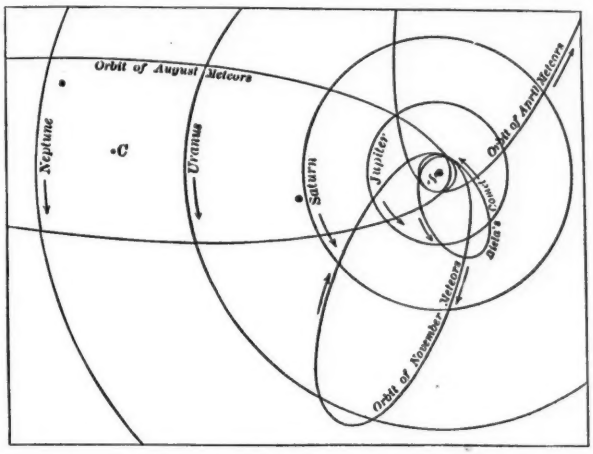


Fig. 3. Orbits of Meteoric Swarms, which are known to be associated with comets.

They intersect the Earth's orbit at certain computed points. We pass through those points on certain nights of the year and the meteoric materials moving in the one orbit collide with the Earth in the other orbit. Now, it has been shown that the orbits of these four meteor streams and of one other stream are the orbits of five periodic comets which have disappeared from sight. Clearly, the cometary materials had been gradually scattered by the disintegrating effect of the Sun's attraction, and the separate particles were compelled to move in orbits differing slightly from each other, and from the recognized orbits of the comets. The meteoric collisions with the Earth are such as to show that we are dealing with widely separated small masses moving in orbits nearly identical with each other.

In the case of these five swarms there is certainly a close connection between meteors and comets. Whether all meteoric matter has come from the disintegration of comets can not be answered now. We can

say that since the Earth actually passes through at least five prominent meteor swarms,[3] there ought to be thousands of invisible swarms within our solar system which we do not pass through. Newton's investigations led him to the conclusion that about 90 per cent. of the meteors which have encountered the Earth and have been observed with sufficient accuracy to let us determine their orbits are moving around the Sun in eccentric orbits of short periods, like those of the short-period comets, and in the west-to-east direction.

The certainty of rapid disintegration of the periodic comets—extremely rapid in comparison with astronomical time-intervals—is all but equivalent to saying that the periodic comets have been recently captured by our planets; for the periodic comets which we are still observing could not have been following their present orbits during many centuries, except at the price of disintegration to the point of total disappearance.

The Zodiacal Light

The zodiacal light is a closely related subject. The phenomenon is due to the presence of countless small particles of solid matter varying perhaps from dust particles up to bodies perhaps many cubic inches or even larger in volume, which scatter the sunlight falling upon them. The volume of space occupied by this finely divided material is very great. It extends north from the Sun to a distance of the order of 100,000,000 kilometers, and there is no reason to doubt an equal southern extension, for observations made in the west after sunset and in the east before sunrise indicate that the structure is symmetrical with respect to the Sun. Its extent in the principal plane of the solar system in all directions from the Sun is even greater. In such clear skies as exist on the tops of mountains the zodiacal light can be seen to stretch entirely across the sky as a faint band following the ecliptic; and this is proof abundant that the materials which scatter the light extend beyond the Earth's orbit.

Inasmuch as we do not distinguish the individual particles which make up the zodiacal light materials, we can not now say whether they are revolving around the Sun from west to east, but we can not doubt the fact that they are revolving around the Sun and that the orbits of a large proportion of the particles are necessarily in planes highly inclined to the general plane of the solar system. Seeliger is of the opinion that this material supplies the attracting mass which disturbs the motion of Mercury, and to a lesser degree the motions of Venus, Earth and Mars. If this be true the total mass of the particles must approximate to that of the planet Mercury.

Where this material came from, whether it is a remnant of the original material which formed the inner planets and the Sun, or whether it has come in from the outer confines of the Sun's sphere of

[3] Numerous minor streams are reported by meteor observers.

influence in the same way that the comets have transported very distant materials into the terrestrial region, is wholly unknown.

Stars Clusters

The star clusters offer a wide range of character, as to their density of stellar contents and as to the symmetry of distribution. There are the large irregular clusters visible to the eye, such as the Pleiades, Praesepe, the Perseus clusters, in which the stars are widely separated and irregularly distributed. There are the globular clusters, invisible to the naked eye, except in three or four cases, which contain multitudes of faint stars densely crowded together and quite symmetrically arranged. The great cluster in Hercules is the most striking example in the northern skies. The accompanying photograph, secured with the 60-inch reflector of the Mount Wilson Observatory, records stars to the order of 30,000, each star a sun as truly as is our star. There are two still more extensive clusters in the Southern Hemisphere, but they have not yet been photographed on the same scale as the northern clusters. The globular clusters, of various degrees of stellar richness, exist to the number of several scores.

There are two great agglomerations of stars—two dense clouds of stars—occupying isolated positions in the far southern sky, quite distant from the Milky Way, which seem to have many of the Milky Way's attributes. They appear to be great irregular clusters of stars differing only in size from the vastly greater Milky Way cluster. These objects are known as the Greater and Lesser Magellanic Clouds.

The Nebulae

The objects which probably concern our subject most directly are the nebulae. The word nebula means a "little cloud"; and like little clouds superimposed upon the dark background of the sky the first 10,000 nebulae looked to their discoverers. They were of various sizes, from that of the Orion nebula, and even larger, down to those indistinguishable in small telescopes from stars, and to those so faint as to be on the limit of telescopic vision. The Herschels, father and son, were the first great discoverers of the nebulæ. Lord Ross's reflecting telescope showed that a few of the very bright and large nebulæ, perhaps two dozen in all, are not formless masses, but spirals—indicating plainly that they have motions of rotation. It was noticed by Sir William Herschel, a century ago, that the distribution of the nebulæ on the surface of the sky is most remarkable. Proctor's chart, published in 1869, illustrates this fact. On this chart the cloud-like forms of the Milky Way are outlined across both hemispheres, as seen by the naked eye, but it should be said that telescopic vision of the Milky Way would present very different and vastly more uniform outlines. Each dot on the chart represents a nebula. He who runs may

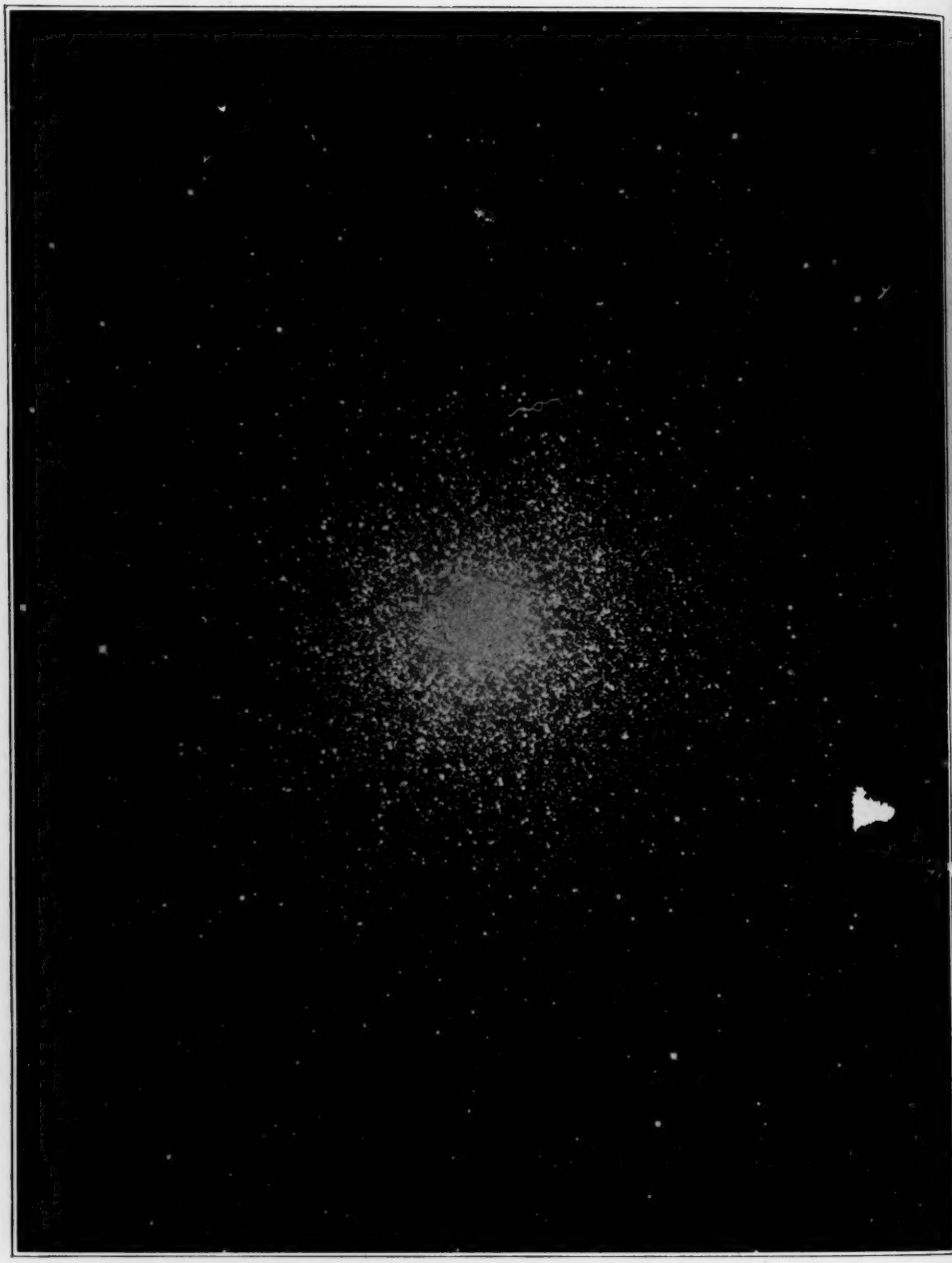
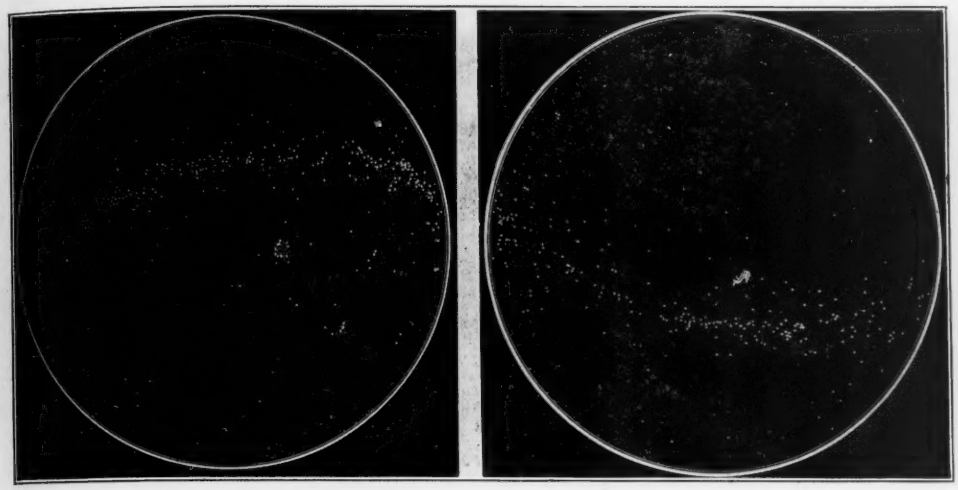


FIG. 4. THE GREAT STAR CLUSTER IN HERCULES. Photograpned at the Mount Wilson Solar Observatory.

read that the nebulæ in general abhor the Milky Way. In the northern hemisphere they cluster most densely in the neighborhood of the pole of the galaxy. In the southern hemisphere they show the same tendency, but not so strongly. There are nebulæ in the Milky Way, but



SOUTHERN HEMISPHERE. NORTHERN HEMISPHERE.

FIG. 5. DISTRIBUTION OF NEBULÆ (AND STAR CLUSTERS). According to Proctor. Nebulæ are marked by dots; clusters by crosses.

they are relatively few. Herschel's and Proctor's conclusions related only to the brighter nebulæ, which had been discovered by visual methods.

Before Keeler began to photograph nebulæ with the Crossley reflector, in 1898, some 10,000 of these bodies had been discovered and catalogued. A few plates exposed by Keeler here and there over the northern sky recorded several hundred additional nebulæ. Using his photographs of small areas of the sky as samples, he estimated conservatively that at least 120,000 nebulæ are discoverable with the Crossley reflector. Further observations by Perrine with the same instrument and by Fath with the 60-inch Mount Wilson reflector have shown that the number discoverable with fairly short exposures is considerably greater than 120,000. Fath's plates, uniformly distributed over the northern sky from the North Pole to declination 22°.5 south of the Equator, recorded 864 nebulæ previously unseen. The numbers on the individual plates are set down in the corresponding area. The curve drawn across the chart represents the central line of the Milky Way. The north pole of the galaxy is at N. The distribution of these faint nebulæ is seen to be patchy, but the fact is in evidence that the faint nebulæ, like those bright enough to be discovered by visual methods, abhor the Milky Way.

Keeler's photography of the nebulæ led him to open another chapter in nebular investigation with the startling discovery that "most of the nebulæ have the spiral structure." This applied not only to the faint nebulæ which he discovered, but to the nebulæ already known. Keeler's successors have confirmed this discovery: it is certain that the great majority of the nebulæ have the spiral form. What the relative number of spirals and formless nebulæ may be remains for the future to de-

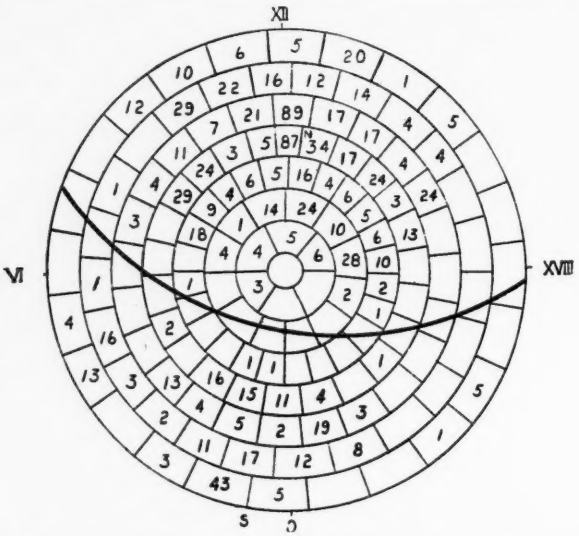


FIG. 6. DISTRIBUTION OF FAINT NEBULÆ DISCOVERED AT MOUNT WILSON.

cide. The spirals vary all the way from the great Andromeda nebula down to those so small that the photographic plate is just able to separate the details of structure; and there is no reason to doubt that more powerful instruments would show still smaller objects to have the spiral structure.

There are irregular nebulæ of all sizes. The brilliant Orion nebula is diminutive in size compared with the faint nebulosity, discovered by William H. Pickering in 1889, which forms the background for almost the whole of the constellation of Orion. The well-known nebulous structure connected with the brighter Pleiades stars is small in comparison with the area covered by a faint exterior nebulosity discovered by Barnard in 1893. There are very great irregular nebulæ such as the Network Nebula in Cygnus and the nebulous background in the Greater Magellanic Cloud. Barnard's wonderful photographs of the Milky Way have recorded many extensive nebulous fields, especially in regions where the background of the galaxy shows relatively few stars (see Fig. 2).

The so-called planetary nebulæ are of special interest, as we shall learn in the sequel. Small in size, all more or less dense, some quite

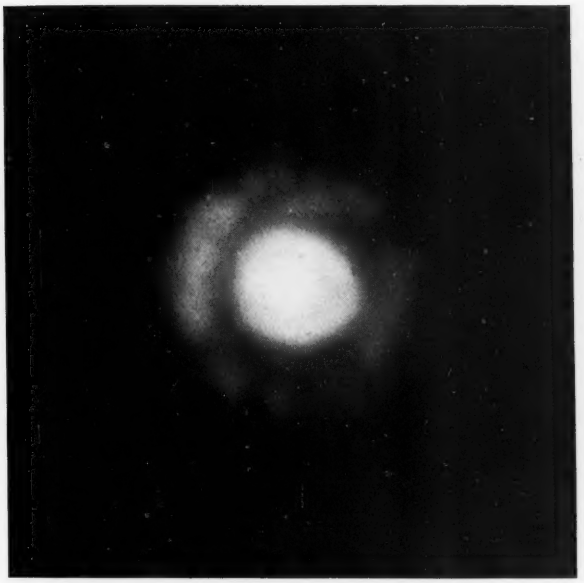


FIG. 7*a*. PLANETARY NEBULA, N. G. C. 2,392. Photographed at the Lick Observatory.

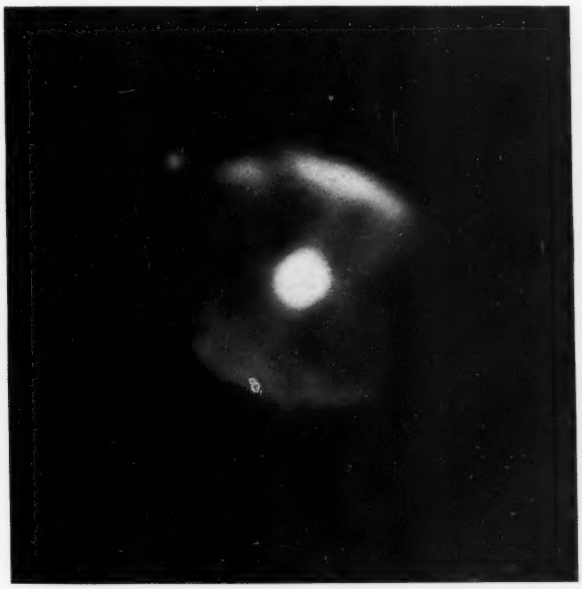


FIG. 7*b*. PLANETARY NEBULA, N. G. C. 40. Photographed at the Lick Observatory.

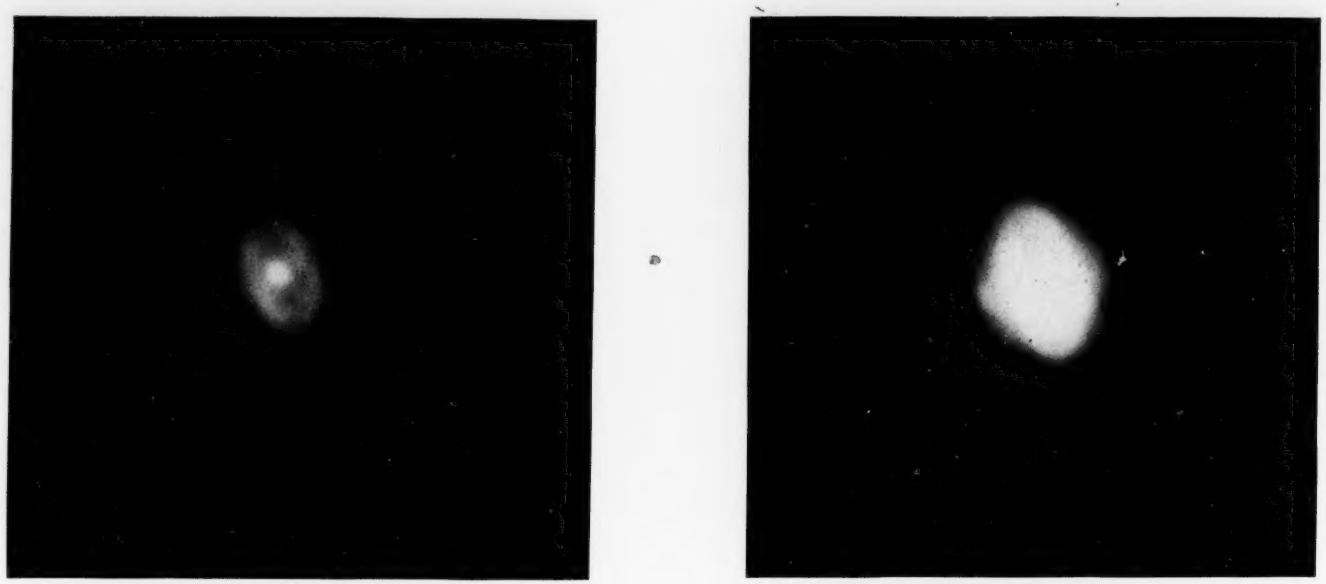


FIG. 7c. PLANETARY NEBULA, N. G. C. 7,009. Photographed at the Lick Observatory.
Two exposures, one short and one long.

regular in outline, and a large proportion containing condensed or stellar nuclei near their centers, they were called planetaries by Herschel, because, though faint, they present discs somewhat as the planets do, when viewed under low power.

There are several scores of so-called stellar nebulæ. In moderate-sized telescopes most of them look like ordinary stars. In large telescopes many of them are hazy, but some are as well defined as stars. The spectroscope shows that all are true nebulæ. If they were much closer to us we should doubtless see them as planetary nebulæ.

A few other interesting objects are known as ring nebulæ, the most noted case being the ring nebula in Lyra.

Among the remarkable facts of the stellar universe are these: the large irregular nebulæ, the ring nebulæ, the planetary nebulæ, and the stellar[4] nebulæ, with relatively rare exceptions, are in or very close to the Milky Way: and, on the contrary, the spirals in or near the Milky Way are of negligible number. The first group are without question an integral part of our stellar system. The spirals, seem not to be closely connected with our stellar system, yet their very avoidance of the Milky Way shows that they bear some intimate relationship to it. There is no occasion for surprise that a small group of special objects should be in the Milky Way structure; but that the scores of thousands, and perhaps hundreds of thousands, of spirals, should abhor the Milky Way is a fact which immediately arrests our attention and calls for explanation. Moore has suggested that their absence from the Milky Way may be apparent and not real; that any absorbing or obstructing medium in the Milky Way structure might prevent the light of the spirals from reaching us, especially if the spirals are extremely distant. If the light from very distant nebulæ is absorbed or obstructed, as a function of the angular distance from the galaxy, the nebulæ near the poles of the galaxy, other things being equal, should on the average be intrinsically brighter than the nebulæ in or near the Milky Way. Secondly, if such an effect exists, long-exposure photographs on regions near the galaxy should record nebulæ in numbers more nearly equal to those recorded by short exposures near the poles of the galaxy. An examination of existing Crossley reflector photographs has led to negative results on this question, and we must assume that the spiral nebulæ really avoid the Milky Way.

The question of the distances of the spiral nebulæ has long been held in mind. The evidence, to which we shall refer later, is to the effect that they are very far away, and accordingly that they are of enormously

[4] The terms irregular, ring, planetary and stellar are intended merely to differentiate these objects as to their appearance in the telescope or on the photographic plate. They do not in themselves indicate differences in constitution or physical condition. The ring, planetary and stellar nebulae have a great many characteristics in common.

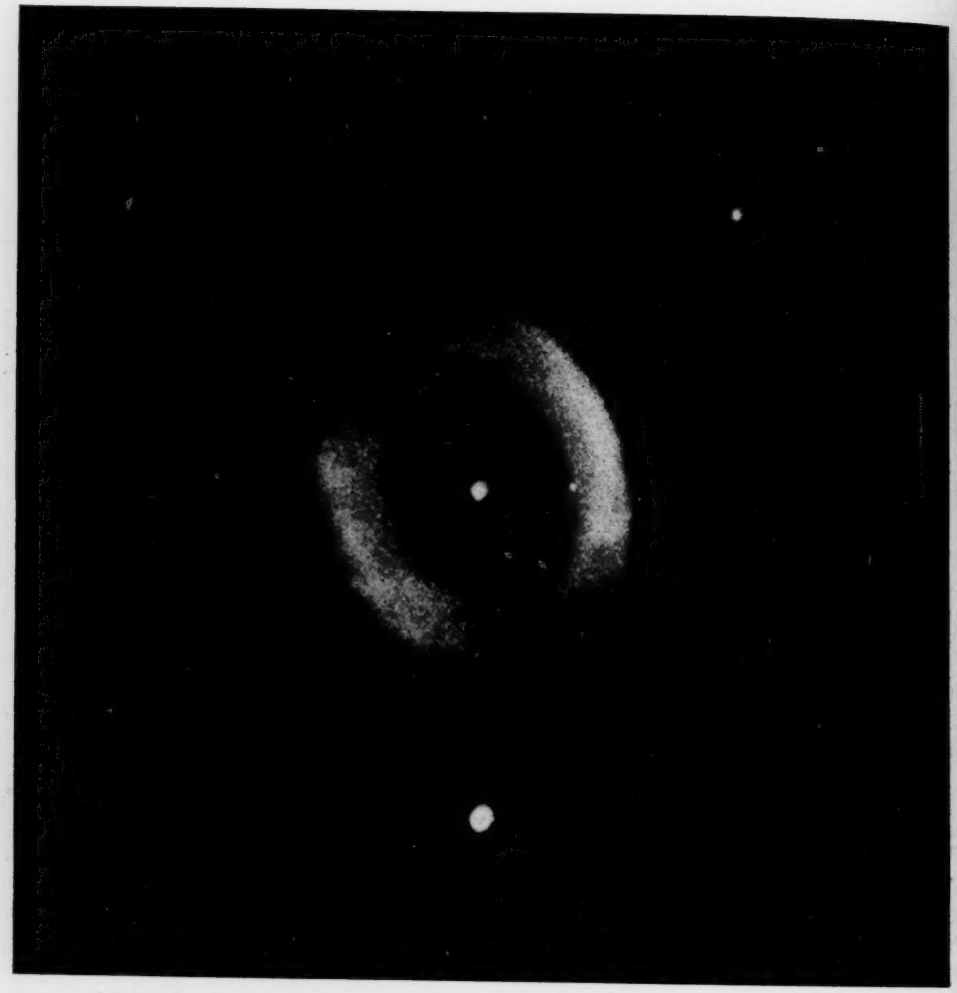


FIG. 8. THE RING NEBULA IN LYRA. Photographed at the Lick Observatory.

FIG. 9. SPIRAL NEBULA IN CANUM VENATICORUM, M. 51. Photographed at the Lick Observatory.

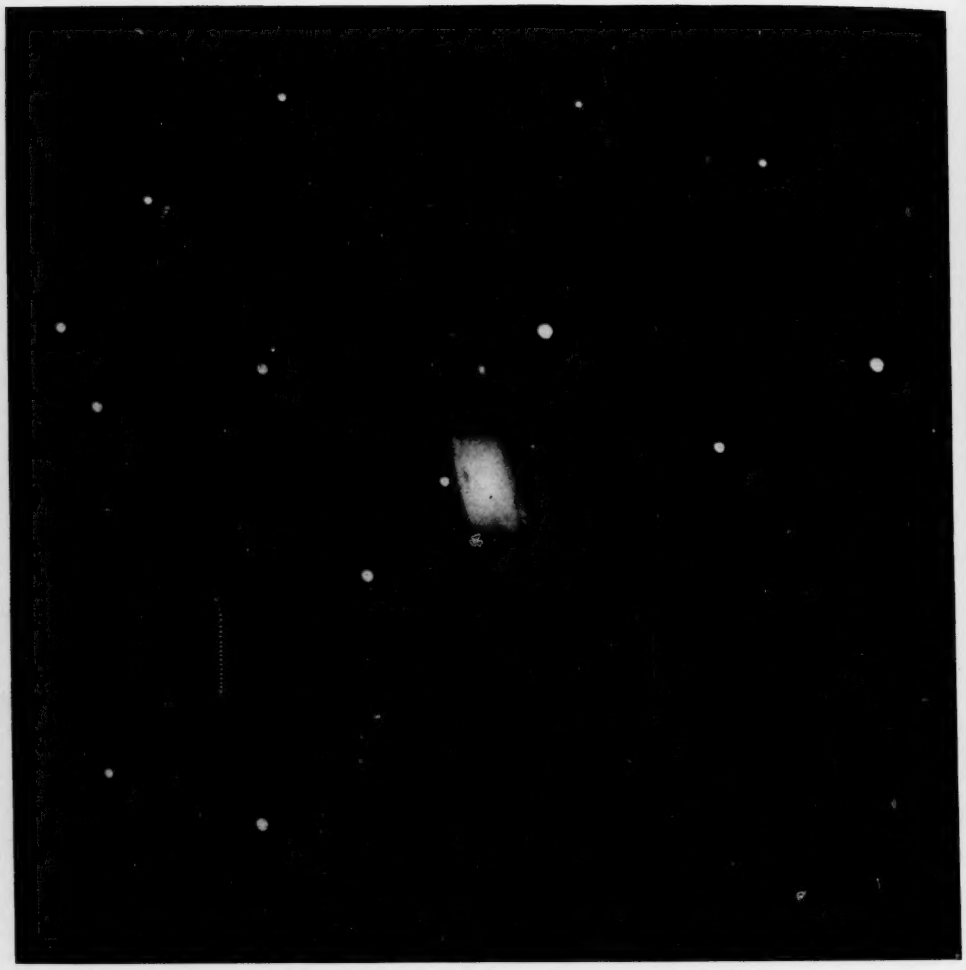


FIG. 10. SPIRAL NEBULA IN LEO, M. 65. Photographed at the Lick Observatory.

great dimensions. This is the particular reason why a few astronomers suggest that the spirals may be distant systems of stars. They say that our own stellar system, if viewed from a great distance, might be seen to have a spiral structure: that it would be fairly circular in general outline if viewed from the poles of the Milky Way, or greatly elongated or spindle-shaped if the observer were in the plane of the Milky Way. We illustrate this point by means of well known spirals viewed broadside, and obliquely, and of the spindle-shaped nebulæ, which we do not doubt are spirals seen edgewise. Easton, the principal modern student of Milky Way structure, has even gone through the laborious task of assigning the stars, as seen from our viewpoint near the supposed center of the stellar system, to their assumed places in a spiral structure. But I need scarcely say that the subject is too vast for solution now, or in the near future. If our stellar system is one of a hundred thousand or more spiral nebulæ, we have at once the problem of determining the place of our stellar system in the larger universe of systems, necessarily beginning with the motion of our system as a whole with reference to the great numbers of surrounding systems.

FIG. 11. THE SPIRAL NEBULA H. V. 41, *Canum Venaticorum*, seen edgewise. Photographed at the Lick Observatory.

STAR STREAMS

It was supposed, until ten years ago, that the stars are moving approximately at random, both as to direction and as to speed. In 1904 Kapteyn announced, on the contrary, that the stars have decided preferences for motions toward two opposite points in the sky; one point in the northern edge of Orion, in the Milky Way; and the other point exactly opposite to this. Investigations by many others have in all cases confirmed Kapteyn's discovery. Kapteyn did not mean to say that the individual stars are moving parallel to a straight line joining these two

opposite points, but simply that their components of motion parallel to this line are considerably greater, on the average, than the components in any other direction. We may visualize his ideas in the following manner:

Assume the existence, ages ago, of a great cluster or cloud of stars distributed more or less uniformly through a certain vast volume of space, whose individual motions were at random in both magnitude and direction. Assume the existence of an entirely similar group of stars, occupying another vast volume of space, whose internal motions were also at random. Assume, further, that these two groups of stars were traveling through space in such a way that they more or less completely interpenetrated, with the result that the two groups of stars have now become a single group. There are stars still moving in all directions, with speeds of all dimensions within certain limits, and yet there exists a preference for motion along and parallel to the line which originally joined the centers of the two groups. Assume now that our Sun is carrying the terrestrial observer through the combined group in a direction making a considerable angle with the line of preferential motion: the apparent motions of the individual stars, as observed from the solar system, would then have preferences for two directions very different from the line joining the two original positions of the groups; we should find a great number deviating by small angles from the two preferential directions, a small number deviating to a greater extent, and relatively few whose motions make large angles with the preferential directions; and this is as the apparent motions of the stars have been determined by many observers.

Kapteyn's results depend upon proper motion data; that is, upon their apparent motions on the surface of the sky. Spectroscopic observations of stellar motions of approach and recession confirm that the stars have preferential motions, but to a smaller degree than proper motion data had indicated.

No one doubts that preferential motions exist, but the explanation is another matter. Kapteyn does not insist that our stellar system has actually resulted from the intermingling of two star streams, yet he inclines more and more to this point of view, and the hypothesis does seem to accord better with the observed facts than any other hitherto proposed. A strong objection to it is its apparent improbability. It does not seem reasonable that two great clouds of stars, containing all the stars now in our sidereal universe, should have come together and interpenetrated so completely as to have produced in an age when we happen to be the observers a stellar system apparently spheroidal in form. When I look at the Milky Way, completely encircling the sky, my mind is filled with doubt. And if two great galaxies of stars have traveled far and come together, they will travel further and through each other and we shall have two galaxies again, moving away from each other. It does

not follow that the more distant and fainter stars will show the same preferential motions as the brighter and nearer ones which led Kapteyn to his hypothesis, though it should be said that a fairly extensive study of stars fainter than the Kapteyn stars made by Comstock led to results in good agreement with Kapteyn's. May it not be possible that the preferential motions observed are in some way connected with rotational phenomena within our stellar system, especially as the line of preferential motions lies approximately in the plane of the Milky Way, or are local to what we may call our region of the system, and not be true of the system as a whole?[5]

An alternative hypothesis of prevailing stellar motions, proposed by Schwarzschild, seems to have advantages from the point of view of probability, but it appears not to accord so well with the facts of observation. Schwarzschild suggests that if from a given point we draw vectors whose directions and lengths represent the directions and speeds of existing stellar motions, then the outer extremities of these vectors will define the surface of an ellipsoid (of preferential motions) having three unequal axes.

(*To be continued*)

[5] Turner has proposed the following explanation of the two star streams: The whole mass of the stellar system exerts a gravitational influence on the motion of each star in the system, and the individual stars revolve around the center of mass of the system in their elongated orbits. One star stream comprises all those stars moving away from the center, and the other stream all those stars moving toward the center. We can not doubt that the motions of the individual stars are influenced by the gravitational attractions of the stellar system and of the group of stars nearest to them; but observational data on stellar motions must be vastly more extensive than at present in order to test Turner's hypothesis.

Halm, of the Cape of Good Hope, has given evidence of the existence of a third star stream, much less extensive than Kapteyn's two streams.

ANT-HILL FOSSILS

By Professor RICHARD SWANN LULL
YALE UNIVERSITY

LAST summer it was the writer's privilege to lead a small expedition from Yale to the fossil fields of the west in search for the relics of bygone creatures to add to the already extensive collections owned by the university. Our purpose was not solely that of collecting, however, but to get data concerning the distribution in time of certain of the ancient faunas, hoping thereby not only to increase the sum of our knowledge, but to date more accurately some of the wealth of forms collected by the pioneer expeditions which, under the leadership of Professor Marsh, penetrated the unknown west in the early seventies.

The work was partly in Nebraska exploring the Tertiary rocks for the remains of warm-blooded mammals—horses, camels, rhinoceroses, elephants, and their kindred—and partly in eastern Wyoming, where one finds sediments of greater age containing the earthly inhabitants of the closing years of the Age of Reptiles. The mammal collecting is an old, old story, but the work in Wyoming had many novel features and forms the theme of this brief essay.

The Mesozoic rocks, those of the Age of Reptiles, are exposed with their contained fossils in many places in this broad earth of ours, but nowhere to a greater advantage than in the west, and this is particularly true of the states of Wyoming, Colorado and Montana. One of the counties of eastern Wyoming, formerly called Converse county, is now divided into two portions, of which the westernmost retains its ancient name, while the eastern part has been called Niobrara after the long Nebraska river whose source lies here. The latter county includes one of the most notable of Mesozoic localities, the beds lying on either side of the confluent Lance and Lightning creeks. The former of these is a tributary of the Cheyenne river, through which its waters flow into the Missouri on their long journey to the Gulf.

The strata here exposed belong to the ultimate phase of the Cretaceous period, marking the very close of the Reptilian age and possibly its passage into the Age of Mammals. They cover an area of more than sixty square miles, and, because of their geographical locality, have received the name of Lance formation, though they have been called variously Converse County beds and Ceratops beds, the latter name having reference to the most characteristic fossils, the horned dinosaurs or Ceratopsia, whose huge three-horned skulls are the most remarkable

features of the formation. Our camp lay near the only available water-hole, in an otherwise dry canyon, tributary to Buck creek, which forms the eastern boundary of the area. From Buck creek the land rises gradually to the summit of the divide, whence it falls away to the level of Lance creek on the west. On the eastern slope the strata, which dip toward the west at an angle of about ten degrees, form a succession of outcrops one above the other as one ascends the hill, so that they may be read in orderly sequence beginning with the oldest in the point of time. Beyond the divide the dip of the strata and the slope of the ground coincide so that the revealing outcrops are absent. To the east of Buck creek, on the other hand, on either side of the little canyon wherein our

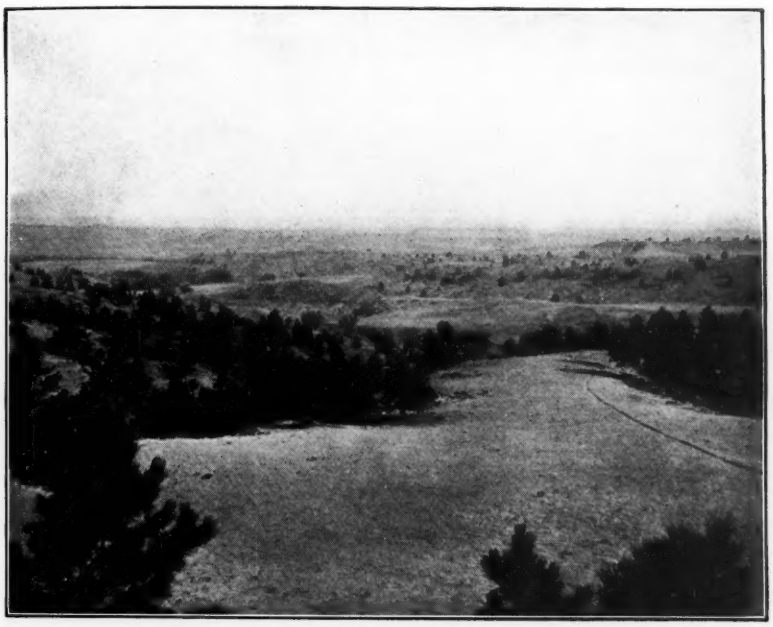


FIG. 1. LOOKING DOWN SPRING CREEK CANYON TOWARD THE CERATOPS BEDS. In the foreground and middle distance the strata are of marine origin—Pierre and Fox Hills formation—the fresh-water Lance sediments lying beyond.

camp was pitched, the rocks, while still late Cretaceous, are older than the Lance formation and of marine origin, for in them the shells of ancient sea-creatures are abundant.

Geologists tell us that during Cretaceous time the continent of North America was covered in part by an inland sea having its outlet to the north into the Arctic Ocean and on the south into what is now the Gulf of Mexico. Along the western shores of this Cretaceous sea were long stretches of low-lying lands gradually rising toward the west to the region of the Rocky Mountains, then in their nascent state. The shore lands, which rarely extended much above the level of the sea, were

subject to occasional inundation when the advancing waters covered what had been land, while their retreat laid bare wide areas which had been submarine. The evidence of this was before our eyes, for as we went westward down the canyons, the sea shells would betray the marine origin of the strata, then as we climbed the slope beyond Buck creek we could see the older sea-borne sediments pass beneath the newer

FIG. 2. LIGNITE BEDS IN THE LANCE, indicating the abundance of vegetation.

Lance formation and become replaced by shales and sandstones of fresh-water origin. Occasionally one came across beds of lignite or woody coal which pointed to an abundance of vegetation, either forest or swamp lands wherein plants must have grown luxuriantly.

Out of this classic locality have come the remains of a host of creatures, the inhabitants of the shores of the old Cretaceous sea, many of which are now preserved in the Peabody Museum at Yale, the spoil of former expeditions. These are mostly dinosaurs, land-living reptiles

which flourished throughout the Mesozoic, but which are here represented in the climax of their evolutionary career. Some were huge-headed forms, armed on the snout and above the eyes with horns like those of cattle and with a wide bony crest which protected the neck. These were quadrupeds of rhinocerine proportions, but of much greater size. Others were bipeds with a long tail which served to balance the body when running on land and was a very efficient propelling organ when stress of circumstance made it necessary to take to the waters for retreat. This second group was armor- and weapon-less, with a curious duck-like expansion of jaws, toothless in front but with a wonderful battery of more than two thousand teeth in the rear of the mouth. Occasional mummied carcases have been found which betray the defenseless condition of the scaly skin. Both of these groups were plant feeders, but a third sort, again erect on the hind limbs, bore teeth and claws which can only mean a rapacious flesh-feeder, doubtless the arch-enemy of the other two. These carnivores were represented by small, agile forms, and by others which were truly gigantic.

The dinosaur remains are pretty widely spread over the present area, the horned skulls generally occurring in hard concretionary masses of sandstone, many of which were collected and shipped to New

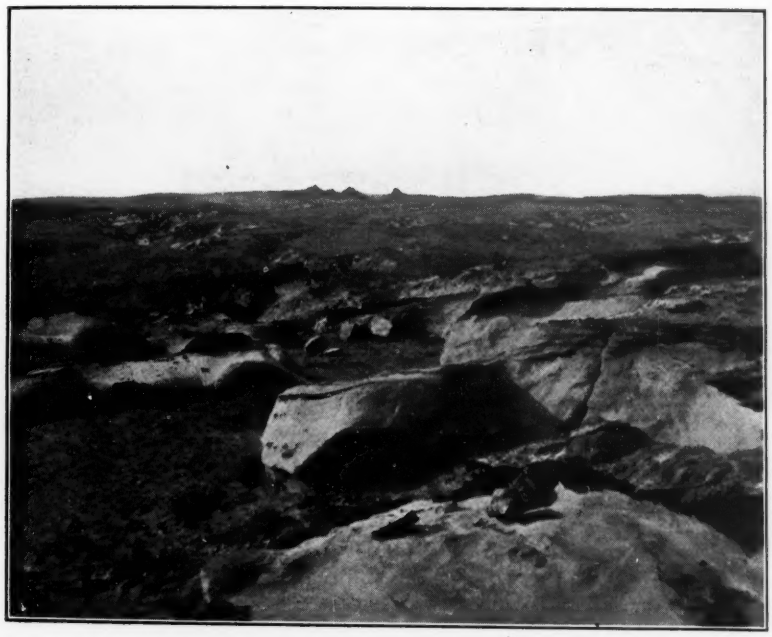


FIG. 3. MASSIVE SANDSTONE WITHIN WHICH THE DINOSAURS ARE ENTOMBED.

Haven and later to the National Museum in Washington, where the contained fossils were freed from the investing rock. Most of the

dinosaur material from this region was collected by John B. Hatcher, a graduate of Yale, and so thoroughly was his work done that very little sign of them now remains. What we of the present expedition especially desired, however, was not to find more dinosaurs, but to hunt for the remains of the tiny mammals, the forebears of the warm-blooded, furry quadrupeds of to-day, which carried on a precarious existence in the midst of such stalking terrors as the giant reptiles.

These mammal remains are known from but few Mesozoic localities and are valued proportionately. By some lucky chance it was discovered that, although they might be found imbedded in the sediments, the most productive places, curiously enough, were the ant-hills. These are numerous and large though in no way differing from those I have found in New England except in the contained fossils. The ants are a lusty breed, valiantly uniformed in brown and black, and with very effective stings, as we have good reason to know. In building their formicaries they not only collect material from the surrounding surface, but in excavating their subterranean galleries the sand and other

FIG. 4. A FOSSIL-BEARING ANT-HILL IN WHICH THE BONES AND TEETH OF THE TINY WARM-BLOODED MAMMALS ARE FOUND.

particles are deposited on top of the growing pile. This was generally a very symmetrical cone with the entrance almost invariably on the eastern side, part way up the slope, while on the western and northwestern aspects the grains of sand were somewhat coarser. We found, however, on breaking into the nest, that the immediate surface was somewhat hardened so as to be distinctly crust-like, while within, until one came to the well-built tunnels, coarse and fine sands were inter-

mingled. It seemed as though the outer crust and the coarse character of the sand on the exposed surface were merely the result of wind and rain which eroded away the finer particles and compacted the surface, and the evidence of the coarser grains on the westward side simply pointed to the removal of somewhat heavier material here than elsewhere by the prevailing westerly winds. I imagine that these winds were also the determining factor in the placing of the entrance, although the idea that the warmth-loving insects might thus have welcomed the rays of the rising sun did occur to me.

It has been found that in addition to ordinary sand-grains certain of the ant-hills also contain fossils, tiny teeth, bone fragments, and in rare instances perfect bones which the ants had unconsciously collected and which have been the source of much of our knowledge of the smaller forms which were contemporaneous with the giant reptiles. It was toward these ant-hills, therefore, that our attention was turned, indeed, they were the object of our journey. I had a rather imperfect map of the region which was supposed to show the place where each important dinosaur specimen had been found and to indicate in a general way the mammal-producing areas. With its aid a very thorough exploration was made, the great majority of the localities which were marked being searched for ant-hills, and these in turn for fossils.

The older method was to shovel the contents of the formicaries into sacs and leave them until the following day, when the ants would have left the material, and then to sift it very carefully, searching for the minute remains of organic life. Much of the "pay dirt" was shipped directly to New Haven, where it could be investigated more thoroughly than was possible in the field. Our time, however, was very limited, so that such refinement of method was impracticable. Then, too, we were not so intent upon adding to the already great collection at Yale as upon determining the exact stratigraphic sequence of the mammal-bearing beds with reference to the geologic column. We therefore attacked the ants' strongholds at once, going over the surface material very carefully, taking the precaution, however, to put a little earth into the entrance and pat it down, thus reducing to a minimum the number of available defenders. The sand was then passed through a common flour sifter and the residue carefully examined, the tiny teeth and bones being removed with a pair of forceps. We did not come away unscathed, for though we brushed aside all the ants we saw, the task would become so absorbing that before one knew it an ant would fix her jaws into the skin and, turning the abdomen under, insert the short but thoroughly efficient sting. After sifting the material we generally replaced it about as it had been found and, as the ants were uninjured, their fabric was probably soon restored to its former symmetry by the tireless little workers, for whom we had a very respectful sympathy in spite of our wounds.

Near Buck creek itself the ant-hills contained only small sharks' teeth, showing that they were still built over marine beds. Then as one mounted the divide and with it crossed higher and higher strata there was a long interval of totally unproductive formicaries, until the principal bed of lignite was reached, and above this, at a vertical distance of ten to fifteen feet, the best of the ant-hills were found, which contained among other remains the bones, scales and teeth of fresh-water fishes allied to the gar-pikes living to-day in southern rivers. These were carefully preserved for comparison with the mammal-bearing sands at Yale collected by the older expeditions, and which were found later to include, in addition to the mammals, fossils exactly similar to those which we secured at this time. That we had found an old locality was further proved by indications of a former camp, fire wood, rusted tin cans, and in an adjacent ant-hill tiny, worn fragments of an unfortunate investigator's spectacles!

The mammalian relics which were thus found were of very small size, consisting of individual teeth or a fragment of a jaw with one or more teeth still in position, or other portions of the bones. Mammal teeth are fortunately highly indicative of habit and relationships; but on the other hand, in collections of this sort, not one bone can be associated with another. Thus, while some idea of the general size and method of feeding may be obtained, no attempt to restore the skeleton or even the entire skull is possible. In size none of the ant-hill mammals was larger than a rat, and many were much smaller. Those whose teeth bore few sharp-pointed cusps were carnivorous, feeding on such feeble folk—insects, worms, and possibly other mammals—as they could overcome. Others with chisel-shaped incisors and many-cusped grinding teeth were plant-feeders, probably living not only on tender leaves, but on berries and the seeds of berries and other fruits.

The little glimpse of a former geologic age which this trip gave us was full of suggestive detail. I have already described the scene as the scientific imagination conjures it up, the broad, savanna-like, low-lying lands over which wandered the huge reptiles then at the very culmination of their evolution. But what of the mammals? Where were they and how did they survive the competition with the dinosaurs? Possibly their very insignificance was their chief safeguard, just as countless small rodents and insect-eating creatures live to-day in the lion- and buffalo-haunted African jungles. Possibly they were tree-inhabitants, and the location of the mammal-bearing ant-hills near the lignite certainly suggests an abundance of near-by vegetation. However we may interpret it, the evidence is clear that these mammals and the dinosaurs were contemporaries in the same general locality though the exact environmental conditions under which they lived may have differed.

Passing back in time some millions of years further, one finds in

rocks which mark the beginning of Cretaceous time as they are exposed in another Wyoming region one hundred miles or so to the southwest, this same association of mammals and dinosaurs, but many of the latter are very unlike their successors and include mighty forms which soon became entirely extinct. But the mammals are practically the same, with little evidence of change, while the reptiles are undergoing their most remarkable evolution.

Again we find the mammals at the close of the preceding Triassic period, this time far to the eastward in South Carolina and then in Germany and South Africa, not in direct association with dinosaurs, but nevertheless in contemporary strata with some of the most primitive of the race. Thus these forebears of modern beasts and men live long ages without measurable progress, while reptilian dynasties wax and wane. But the mammals, with the tenacity of their race, are merely awaiting their opportunity, although so effective is the check laid upon them by their cold-blooded contemporaries that for them evolution practically ceases while the march of time goes on. At last comes the day of reckoning when, due to some cause or causes of which we have not yet learned the nature, although they were doubtless conditioned upon the mountain-making revolution which closed the Age of Reptiles, the dinosaurs, after their multi-millennial career, are blotted out and the Age of Mammals is begun. Now from their fastnesses stream the furry hosts, impelled by age-long earth hunger, to fill every station in the economy of nature which the reptiles had possessed, and now the evolutionary mill, turning faster and faster, grinds out the beasts both small and great which become in their turn the rulers of the earth until their place is usurped by humanity.

FOUR POINTS IN THE INDICTMENT OF THE SMOKE NUISANCE

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IN all papers and talks concerning the smoke nuisance, it has become customary to refer to the economic cost of the nuisance both to the public and to the smoke makers. This is the indictment which is supposed to strike home. When a speaker on this subject says

> The abolition of the smoke nuisance, unlike many other social nuisances against which outcry has been, would result in direct and immediate gain both to the public at large and to those who are chiefly responsible for the nuisance itself,

he feels that he has said the last word.

There are other points in the indictment of the smoke nuisance to which attention may more properly be directed. It is the purpose of this paper to tell of the present knowledge on four of these points, namely:

1. The effect on building materials.
2. The effect on meteorological conditions.
3. The effect on vegetation.
4. The effect on health.

There has been much talk within the last few years concerning city planning. The principal idea that city planning seems to convey to most people is a beautiful and costly square, set in the center of an ugly city. All real city planning should have as one of its main objects the purification of the atmosphere. Some forty years ago, John Ruskin, speaking to the Society of British Architects, said:

> All lovely architecture was designed for cities in cloudless air. . . . But our cities, built in black air, which, by its accumulated foulness, first renders all the ornament invisible in distance, and then chokes its interstices with soot; . . . for cities such as these, no architecture is possible.

An architect in a smoky city is forced to take atmospheric conditions into account. Drain pipes must be arranged with great care—that there may result no splashing of the soot-carrying water to discolor the sides of the building. Mouldings must be so designed that the rain will not wash over the face that soot which collects on top of the mouldings. Drips must be provided on all projections. Under-cutting, delicacy of incised line and sharpness of angular forms must be foregone, for the soot deposited will, in time, fill up the crevices and mar the

beauty of the outline, causing considerable alteration of the original forms and making the building degenerate into a mere mass of dirty, shabby masonry.

It is rather interesting to note the vogue of such materials in buildings as glazed brick and terra cotta, in smoky cities. Stone, for which they are substitutes in many cases, is injured by smoke and the associated products of combustion in two ways:

1. The soiling of the surface, so that in the course of a few months all stone takes on the same gray, grimy color. This means either the loss of all artistic effect that may have been obtained by color contrast, etc., or the frequent cleaning of the building, which is an additional expense and at the same time aids in the destruction of the stone.

2. The actual destructive action on all stones by the acid products of the combustion of the coal. This is especially marked on any stone containing calcium or magnesium carbonates in larger or smaller quantities. Although there is some action on other constituents of the building stones, it is so slow in most cases as to be hardly noticeable.

A study was made in connection with the smoke investigation of the Mellon Institute as to the effect of smoke on outside painting.[1] Both the effect on paint as a protective coating and as a decorative covering was considered. It was found that some paints last comparatively longer in Pittsburgh than in many other cities. This is in part due to the protective action of the soot in preventing the destructive action of the active rays of the sun. This would also indicate that such paints might afford a lodging place for fungi, which grow in the absence of direct sunlight.

It was found that smoke darkens paint coatings very rapidly and renders the use of light colors unsatisfactory on account of the short time they retain their true color. Analyses of the surface of the paints showed that the darkening was due to sulphur dioxide gas and to the accumulation of soot, carbon and similar organic matter contained in smoke.

The effect of smoke on metals must be taken into consideration in connection with the other building materials. When soot containing tar comes in contact with a metallic surface, it is made to adhere more or less firmly by means of its tar content. The occluded acids, principally sulphuric and sulphurous, are thus brought in intimate contact with the metal, giving a much better chance for corrosive action to take place and for it to become complete quicker than if the same amount of acid dissolved in rain water came in contact with the metal. The acid in the rain water drains off readily, while the soot protects the occluded acid to a great extent, so that it remains in contact with the metal until it has all been used up.

[1] Benner, Raymond C., Bulletin No. 6, "Papers on the Effect of Smoke on Building Materials," 1913. (Published by Mellon Institute.)

Inquiry in Pittsburgh among metal workers developed the fact that metal work in a smoky city lasts only half as long as in one free from smoke.

It is hardly necessary to point out that smoke damages the interior decorations of a building or home, limits interior decorators in the use of colors and materials and in every way tends to render artistic effects gloomy and depressing.

Cities very properly hold favorable climatic conditions as a very desirable asset, as is evidenced by the records of rainfall, temperature, fog and hours of sunshine which appear in the year books of the chambers of commerce and boards of trade of the different cities. Cities which have smoky atmospheres are under a severe handicap in this regard.

In the first place, while smoke is not a cause of fog, it intensifies a fog when it is once formed and accordingly causes it to persist longer.[2] In consequence of this there are fewer hours of sunshine in smoky cities than in cities which are practically free from smoke. Again, the sunshine is less intense in smoky cities, the light of short wave lengths, or the blue light, suffering the greater depletion. Not only is this true, but daylight, which depends entirely upon diffused light from the sky, is depleted by the smoke in greater proportion than the direct sunlight.

Experiments carried on by the Smoke Investigation of the Mellon Institute in Pittsburgh and Sewickley, a small residential town on the Ohio River, about twelve miles northwest of Pittsburgh, during 1913, revealed that Pittsburgh had 25 per cent. less sunlight and 40 per cent. less daylight than Sewickley. It was also found that the limit of visibility in the business section of Pittsburgh was about one tenth the limit in the open country. It is well known that the frequency of intense fogs in London has decreased and the hours of sunshine increased since 1890, due to a mitigation of the smoke nuisance. The same was true of Pittsburgh between 1885 and 1895, when the use of natural gas for manufacturing and domestic purposes was quite general.

A number of studies have been made of the effect of soot on vegetation. Cohen and Ruston, as a result of their researches in Leeds, England, declared that soot may exert a detrimental effect on the growth of plants in three ways, namely, by blocking up the stomata and thus impeding the process of transpiration; by coating the leaf and so reducing the intensity of sunlight, and at the same time affecting the assimilation of carbon dioxide; and lastly, by the corrosive effect of the acid it contains.[3] Experiments they carried on went to show that the power of assimilation of laurel leaves had a definite relation to atmospheric

[2] Kimball, Herbert H., Bulletin No. 5, "The Meteorological Aspects of the Smoke Problem," 1913. (Published by Mellon Institute.)

[3] Cohen, Julius Berend, and Ruston, Arthur G., "Smoke: a Study of Town Air," 1912.

impurities, that crops of radishes and lettuce grown in different sections of Leeds show the possibility of correlating the known atmospheric impurities with the yield of the crop. They also found that as trees automatically keep a record of yearly growth, the presence of any inhibiting factor will make itself known by the narrowing of the annual rings.

In 1913, a study of the effct of city smoke on vegetation was made in Des Moines by A. L. Bakke, of the Iowa State College.[4] Mr. Bakke reached the following conclusions:

1. That gases and smokes have a deleterious action upon vegetation.
2. That the vegetation about a manufacturing concern may be mapped off, in the form of concentric belt demarcation, each belt being represented by a certain form or forms of plant life, since certain plants are more susceptible to smoke injury than others.
3. That an industrial city like Des Moines, in its plant elimination process, is governed by the same set of conditions as are in operation for a single manufacturing plant.

Mr. J. F. Clevenger, as a result of his studies in connection with the Smoke Investigation of the Mellon Institute, declared that the fact that smoke injures vegetation is evidenced not only by the general external appearance of many of the constituent plants, but also by their internal appearance, as shown by the size of annual rings and by lesions in the leaves.[5] Mr. Clevenger's studies were confirmed by controlled field experiments which he made. In these experiments growing plants enclosed in cases were subjected to small quantities of soot distributed uniformly over them. The leaves of the plants so treated displayed a tendency to drooping and many of the leaves began to die at the tips; a checking of growth of the plants was also apparent.

The effect of smoke on health has been a much-mooted question. For a long time it was held, and still is by some, that a smoky atmosphere is not injurious and at times even beneficial to public health. This supposition gained favor from an observation, largely erroneous, that coal miners are not prone to contract tuberculosis.

One of the most comprehensive studies of the direct effect of smoke upon the respiratory organs was made by Dr. Louis Ascher, of Königsberg. Dr. Ascher's statistical and experimental studies led him to the conclusion that the mortality of acute lung diseases is certainly increasing, especially among children and old people. The cause of this increase, he declared, is the impurification of the air by smoke, as the increase is greatest in industrial centers and not in agricultural districts. He further pointed out that within industrial districts a difference in

[4] Bakke, A. L., "The Effect of City Smoke on Vegetation," Bulletin 145, Iowa State College of Agriculture.

[5] Clevenger, J. F., Bulletin No. 7, "The Effect of the Soot in Smoke on Vegetation," 1913. (Published by Mellon Institute.)

mortality can also be noted, the death rate from acute lung diseases, in districts with much smoke, being higher than in other industrial centers with little smoke as textile districts.

The physicians who worked in cooperation with the Smoke Investigation of the Mellon Institute made valuable contributions to the question of the relation of smoke to health.[6]

Dr. W. L. Holman, investigating the bacteriology of soot, arrived at the following conclusions:

1. Soot has a definite bactericidal action on bacteria, due either to the absorption of moisture from the organisms or more probably to the action of its contained germicidal acids and phenols.

2. Soot, as it occurs in smoke, clouds, fogs and as a non-transparent covering for our streets and houses, protects microorganisms from the destructive action of sunlight.

Dr. Oskar Klotz, attacking the subject from the viewpoint of a pathologist, asserts that pulmonary anthracosis—a term applied to a condition in which carbon particles of extraneous origin are deposited in the lungs—is an urban disease and is proportionate to the smoke content of the air. His examination of the lungs of adult individuals resident in Pittsburgh shows that they have materially more carbon deposit than the lungs of individuals resident in a lesser manufacturing community.

Dr. Samuel R. Haythorn, attempting to determine whether or not excessive deposits of dust and coal pigment within the body tissues have or have not any "real disease" significance, arrived at the conclusions:

1. Moderate anthracosis in an otherwise normal lung is not in itself detrimental to health.

2. In tuberculosis, the anthracotic condition is either entirely passive or is active in assisting healing, in that it aids in the localization of the process through the obliteration of the lymph spaces.

3. In the case of pneumonia, the effect of carbon deposits in the lungs is quite different. The carbon blocks up the lymphatic spaces and causes obliteration of the lymph channels. This results in serious intereference with the drainage system of the lungs and thus delays, if it does not make impossible, the resolution of the pneumonic process. An anthracotic lung has, therefore, less chance of recovery from pneumonia than a lung which has not undergone changes from the deposit of carbon.

Dr. William Charles White, from a study of the relation of the mortality from tuberculosis and pneumonia to the smoke content of the air, shows that, in Pittsburgh, pneumonia increases with the density of smoke irrespective of the density of the population or of poverty. Tu-

[6] Klotz, Oskar, and White, Wm. Chas., Bulletin No. 9, "Papers on the Influence of Smoke on Health," 1914. (Published by Mellon Institute.)

berculosis, on the other hand, he shows to be independent of the smoke density, following, as it does everywhere, the line of overcrowding and poverty.

In summarizing the results of all medical investigators whose opinions are based on other groups than theory, it can be asserted that smoke has a tremendous influence in increasing the incident severity and mortality of acute disease of the air passages. It would appear that this increased susceptability is, in part, the result of the lowering of our natural body resistance. In simple terms, the smokier the atmosphere, the more the colds and bronchitis, and the more money paid to doctors.

It would seem from a consideration of the four points that have been discussed that it is high time for the people to arouse themselves from the apathy that they have shown toward the smoke nuisance. The purification of the atmosphere should receive the same attention as pure food and pure water are receiving, for it is just as important. People should be educated as to the evils of the nuisance so that an active and intelligent public opinion could be brought to bear on those who are responsible for it. The demand should go out that the nuisance be abated as a menace to health, property and the things which make for civic betterment.

A CIVIC INVESTMENT

By President P. R. KOLBE
MUNICIPAL UNIVERSITY OF AKRON

IN these modern days of municipal extravagance, of crowded city budgets, and of frantic legislative attempts to control undue rates of taxation in our centers of population, any new source of expenditure is almost pre-fated to encounter the shrug of suspicion—the stony stare of hostility. Even the propagandists of municipal ownership demand their pound of flesh—the new venture must pay for itself in hard cash.

What claim then has higher education upon the purse strings of the city taxpayer? "Support a college with city money?" grunts the rich manufacturer, "Not by a long shot; what this town needs is more paved streets, not Greek and Latin students." Did it ever occur to you that to the average business man all college graduates are "Greek and Latin students"? Many expressions have become so formalized that they are inevitable—they slip from the lips as naturally as "the sunny south" or "the great metropolis" or any other of the thousand and one substitutes which our jaded minds employ in the place of real ideas. So it is with education. All students learn "Greek and Latin," all education is "impractical." Ten to one the man who uses these terms has not been inside an institution of higher learning for years—probably never. If salvation itself were at stake he could not name half a dozen subjects taught in the modern college—"Latin and Greek" he would tell you "Ah, er—yes, Latin and Greek and—well—I really can't say, but anyhow it's all quite impractical!" He doubtless has inherited this idea as he did his politics and religion, but in both of the latter, he has kept more or less abreast of the times. In the case of higher education, though, he has never given the matter sufficient independent thought nor investigation to modify his grandfather's viewpoint, and even the most partisan supporters of education must confess that that old gentleman would perhaps have been right, had he called the education of his day "impractical." In the course of the next few years, I believe, the leaven of the "new education," the actual preparation for life, will have worked itself in to the very center of the lump—will have educated not only its students directly, but working through them, will have inspired a wholesome respect in all the people for the practical efficiency which many of our best colleges are imparting to their charges—all of which brings me back to my real subject, the municipal university.

The municipal university represents one of the newest, the most

modern types of education for the purpose of practical efficiency. With the examples of the great state universities ever in mind, it has realized that the highest mission in its field lies in service to its community. Since the services which education may render to a city are somewhat different from those which it may render to a state, the municipal university has had a new problem to solve or rather should I say—*has* a new problem to solve, since both the conception of the problem and the attempts at its solution are still in their infancy.

Our country to-day possesses only half a dozen municipally supported institutions of higher education. As a matter of fact, in the old sense of the word, we have only one municipal *university*—the University of Cincinnati. Other municipal institutions of collegiate rank (my own among them) have assumed the title "municipal university," in the face of educational disapproval of the term, largely for the reason that our language offers no name to characterize a school which has outgrown the limits of the old fashioned college, which has actually established other schools than that of liberal arts, but which does not possess all the professional faculties. For such institutions, in view of their close cooperation with various city departments and in further view of the fact that a development along practical and technical lines has multiplied the number of their schools to a greater or less extent, the name "municipal university" seems not ill chosen.

The keynote of a municipal university must ever be public service—not that somewhat indefinite public service which gives young people a "broad, general education" (too often a euphemism for a mere smattering of many subjects)—but rather that public service which will awaken in our young people a consciousness of their relation and responsibility to the community and which will actually train them for life and for civic duties.

The recent meeting held in New York at the call of Mayor Mitchel under the auspices of the American Political Science Association's Committee on Practical Training for Public Service discussed as its main topic the service of the university to the community. The same topic engaged the attention of the Urban University Association at Washington last November. This meeting marked an epoch. For years it has been growing more and more apparent that every collegiate institution which exists tax free in the midst of a large community does owe an actual debt to its city. This feeling has doubtless been strengthened by the attitude of a few municipal universities, notably Cincinnati, who have been trying to make some practical return for the money which taxpayers have given them. Just how this can be done is one of our most important modern problems. With the feeling that New York offers an unparalleled field for such activities the New York conference adopted a resolution calling upon the College of the City of New York to institute

a series of experiments along this line, whose results should serve to guide other institutions toward the same goal of public service.

Meanwhile, the middle west has been working out its own salvation as regards the public duties of city bred educational institutions. Ohio with its three municipal universities at Cincinnati, Toledo and Akron, leads its neighboring states in this respect.

When Akron, a city of 100,000 inhabitants, established such an institution upon the foundation of the old Buchtel College, many, good citizens shook their heads in doubt as to whether a city of this size could afford the "luxury" of higher education. Fortunately, however, the young people of the city saw in this opportunity not a luxury but a chance for practical preparation for life. In the two short years of its existence, the university is already beginning to be one of the strongest factors in the community for civic betterment.

Why can a municipal university offer more practical education than other colleges or universities? As a matter of fact, any private institution *can* do as much. The municipal institution has simply by force of its position, heard the call more clearly and for this reason leads the way. Its activities are divided into two general lines:

1. The training of students.
2. Cooperation with city departments and activities.

Either one of these two is impossible without the other. Students can not be trained for practical life without contact with actual conditions. Such contact can only be secured when every department of the university is in close cooperation and contact with that part of civic life to which it is most closely related. On the other hand, such contact can only be secured by putting students directly into the activities mentioned and thus forming the connecting link between city and university.

The beginning of this contact was made at Cincinnati about eight years ago, when Dean Schneider established his courses in engineering on the cooperative plan. It is scarcely necessary here to mention the merits of this much discussed system. In brief, it means that engineering students work for alternate two-week periods in class room and in factories, under actual shop conditions. Thus a graduate from this course is not a mere theorist, but knows manufacturing and engineering from the standpoint of personal experience.

To students of economics and sociology an especially broad field is open for experience with the conditions of actual life. In my own city, a thorough housing survey has been carried on by university students under the joint direction of the department of sociology, the charity organization and the board of health. Nor has this work been mere play with no practical use. As a result of reports brought in by student inspectors, the sanitation of houses and even of whole districts has been improved through vigorous action of the building inspector. The city has been benefitted by enlisting in its service a body of capable in-

spectors at no cost, while the students have received credit at the university for "laboratory" work.

When the city of Akron established its municipal university, it was found that the university laboratory offered better facilities than that of the city chemist. In order to avoid expensive duplication, the university thereupon undertook to carry on in its laboratories the entire testing work of the city and established as one of its departments a bureau of city tests. Again the practical value of cooperation became apparent. Advanced university students in chemistry, instead of working at mere theoretical problems, were given actual city chemical testing work. The difference became at once apparent. A student who plodded through a "book problem" as drudgery, became an active, interested worker in the solution of a real food problem affecting the health of his community. The value of chemistry as an actual factor in life became apparent. At the same time, certain students were receiving experience which would later enable them to enter, well equipped, into a life calling.

When the city council, feeling the need for information, asked the engineering department of the university to undertake a survey of paving conditions in the city, cooperative students were called in to help in the work of inspection. When the need arose for a supervisor of city playgrounds, the physical director at the university was called upon to assume the position. Several of his sub-directors are city university students. Thus the city is beginning to regard the university as a laboratory to which it may, at any time, turn for technical advice and help. Through experience with problems thus offered, students are given the opportunity for training in the service of their community. They are taught to study and know city activities and interests—they become better citizens.

The state university offers free tuition to all who can take advantage of the opportunity. The city university also offers free tuition to its community, a practical training for life, and the advantage of a higher education *at home*. This latter fact opens up possibilities to hundreds of students who could never attend even a state university. A cooperative engineering student, who earns apprentice wages during his alternate two week shop periods and who has the privilege of living at home can secure an education and support himself at the same time.

From all parts of the country come inquiries from cities regarding the operation of a tax supported municipal university. Cleveland has considered a plan by which her students may receive free higher education at a municipal university formed by a coalition of her great privately endowed colleges. The day of the municipal university will come as inevitably as has that of the state university. Municipalities are already beginning to realize the possibilities of *practical* higher education as a civic investment.

SCIENCE AND DEMOCRACY[1]

By M. E. HAGGERTY
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REVOLUTIONS are a part of our modern world. Men have come to look upon them as natural moments in national life. So much experience have the western nations had with social upheavals and the reversal of political practises that they have learned how to revolute without war or violence.

To many thoughtful men, we are now in the midst of such a peaceful revolution. In America, England, Germany, old ideals are being forsaken and settled institutions are submitted to a criticism that unsettles their foundations. Everywhere, in religion, politics, industry, education, there is the antithesis between conservative and radical, the latter bringing about the ears of the former a perfect storm of clamor and bewilderment. In America we incline to view the current tumult as the fallow ground out of which is to spring a new and better form of social organization. The evident unrest is but the symptom of fundamental changes going on. It indicates the recasting of our ideals into a new and larger program of democracy.

Clearly to apprehend the portent of our current confusion, one needs to look below the symptoms for the cause. The fires of significant revolution are never kindled on the surface. They smolder in secret places and in obscurity gather the strength which overturns existing institutions. The overt crisis comes finally as the breaking forth of a long suppressed flame. So was it in France in 1789; so was it in America in 1860; so was it in China in 1912. So is it in all our western world in this year of grace. Causally contributing to our present ferment there

[1] This paper was read to the Indiana University Chapter of Sigma XI, December 11, 1913, and subsequently to the Liberal Lecture League at Indianapolis. On superficial reading it may seem that some of its claims have been refuted by the present European war. To the writer it seems that the development of mankind is a deep movement in which the present war, terrible and reactionary as it is, is an episode. Its most harmful effect upon the march of civic emancipation will be the economic one, the destruction of the means of life. When the "glorious victory" shall have been won there will be less to eat than before. The "strong man" will get his disproportionate share, and the common men who are left in Europe will be hungry. They will be less aggressive than before, and the tide of economic liberation which was steadily rising in 1913 will be stayed. But a new generation will be born to try again the fight for freedom. Some day that fight will be really won and Europe will forget William III. and Nicholas II. as France has forgotten Napoleon and as we have forgotten George III. To the achievement of such oblivion science lends its indirect but powerful aid.

are doubtless numerous causes, but there is probably none more potent than the phenomenal growth of science in the past hundred years. If we are about to have a new democracy it is because science with a thousand charges has shattered old ideas and institutions into fragments and given in their stead the materials for new constructions.

Primary in this relation of science to democracy is the change which has been wrought in the economic status of the men who work with their hands. As not before in the history of mankind, laborers may have food, they may have schools, they may travel and wear good clothes; they may have household conveniences, baths and lighted rooms, unknown to kings and nobles of a century ago. In fifty years our civilization has changed from one of deficit to one of surplus and the specter of a near world famine has disappeared.

For a hundred years following 1798, men were taught that their welfare depended upon the limitation of the population. Malthus had pointed out that the produce of the world could be made to increase in but an arithmetical ratio, while the unrestrained human race was enlarging in a geometrical ratio. The economic deficit which the world faced at the beginning of the nineteenth century could on this theory only become greater and greater until the whole race of men would be struggling for the insufficient fruits of a niggard earth. But in the very hour when Malthus and John Stuart Mill were most orthodox the theory was being already discredited by a change in the world's production. From an earth which gave too little for the sustenance of her children we have come to a condition where men live in the midst of abundance. We are not so much troubled now by the scarcity of food as by its inadequate distribution. "For the first time in the history of civilization" writes Prince Kropotkin, "mankind has reached a point where the means of satisfying its needs are in excess of the needs themselves."

For untold generations, slaves and peasants and farmers had gotten with pain the barest subsistence from the soil, but, suddenly, as if by magic, two blades of grass began to grow where one had grown before and an acre which had yielded thirty bushels of corn began to give fifty and sixty and a hundred. The area for the cultivation of foods was widely extended by the development of the American continent and exploration and colonization in South America and Africa. New articles of food came into existence. Beets, hitherto but a food for cattle, began to give sugar, and tropical fruits, especially the banana, found their way to every market in the world. The tomato, long suspected of being poisonous and, down to the middle of the nineteenth century, distrusted as a possible forerunner of cancer, has become a food staple. The potato, unknown before the sixteenth century and at the beginning of the eighteenth regarded as a fit food only for swine and

cattle, has assumed the place of chief economic importance among garden products. Twenty-five years ago the European crop of potatoes exceeded in value the entire wheat crop of the world. In the United States in 1912 the increase of potato production over the average of the preceding ten years was 100,000,000 bushels, an additional bushel for every person living within our borders.

A bit of statistics may emphasize the fact of our increasing surplus. The increase of rural population in the United States between 1900 and 1910 was 9 per cent. In the same period the production of wheat increased 31 per cent.; of corn 47 per cent.; of rice 82 per cent.; and the value of all farm property over 200 per cent. Paralleling the rapid advance in agricultural production has been the increase of mineral products. In the decade the production of copper increased 40 per cent.; of zinc 7 per cent.; of iron 69 per cent.; of petroleum 131 per cent.; and of coal 140 per cent. At the same time, the products of manufacture increased far faster than the population. While the latter went forward 21 per cent., the former advanced 84 per cent. How directly this bears on living conditions appears in the fact that the manufacture of food products and textile articles constitute more than a third of the total and show an increase in ten years of 83 per cent. To see how manufacture tends toward the food surplus, one needs but to look at the grocer's shelves. There safely packed away in cans, bottles, cartons, are the seasonal surpluses of widely distant zones. Vegetables, fruits, fish, meats hide behind attractive covers and await the capricious appetites of purchasers. Here one sees also how transportation by rail and boat has eliminated zonal boundaries. Australia, South America, Europe, Asia, and the farthest corners of our own continent are here brought together. The typical American epicure knows no season and no territorial zone. On Christmas day he eats fruits his progenitor of a half century earlier could have had only in June, and in New York he pleases himself with foods available to his ancestors only after ten thousand miles of travel.

To think of a near world famine in the face of these modern wonders of production and distribution is to be disturbed by a dream. The world can now produce more than it can properly consume and the production is increasing at a faster rate than is the population. If there is still hunger in America, it is not due to the scantiness of food. It is due to the inequality of distribution, an inequality, however, that is not static or necessary. We can rest assured that as soon as society has partially recovered its feet after its headlong plunge into wealth, it will set itself to rights and care for every man as he needs. At the present time there are searching efforts being made to ascertain the adequate standard of living for men of various occupations. That that standard will be met out of society's rapidly accumulating surplus is as

sure a conclusion as that the anti-toxin for infantile paralysis will be used when once it is discovered.

One of the surest indications of what this means for the laboring man is the steady increase of estimate of the salary necessary for efficient living. John Mitchell fixed it at $600 for cities of less than one hundred thousand population; Streightoff said $650; the New York State Conference of Charities and Corrections say $825 for a family of five, and the Bruères say $1,200 per annum is the minimum upon which a family of five can maintain an adequate degree of industrial efficiency. The fact that we have come to the place where such standards can be set is an augury of the future of our working people. Involuntary poverty is as sure of elimination as anything in human affairs can be. Time, struggle, courage, patience, individual sacrifice, intelligent handling of the growing surplus, will bring us the new day of economic freedom. With that will be established the real basis of a democratic society, a society in which there will be the possibility of individual distinction coincident with the improvement of the whole state, the two guaranteed by a government in which the sovereign is the whole population.

The period which has seen this reversal of economic conditions is likewise the century of greatest scientific advance. By 1800 Newton had established the law of gravitation; Harvey had discovered the circulation of the blood Linnaeus had developed a biological classification and nomenclature, Buffon had written fifteen volumes of natural history, feeling his way toward a theory of organic evolution, Cavendish had discovered hydrogen, and Priestley, oxygen, while Lavoisier had constructed a chemical nomenclature and discovered the composition of water; surgery had been practised by Hunter and Haller, and physiology and anatomy were subjects of study; Locke, Berkeley, Condillac had originated the doctrine of sensationalism in psychology, and Kant had completed Hume's theory of ideas by denying the possibility of knowing anything beyond the phenomenal world.

Released from the domination of false theology and bad metaphysics, the youthful sciences took mighty steps in the early years of the nineteenth century. Cuvier and Lamarck in biology, Young, La Place, Volta, and Carnot in physics, Dalton in chemistry, were followed a little later by Davy, Faraday, Arago, Ampère, Owen, and a vast army of lesser men. By the middle of the century the pendulum had swung heavily in the direction of biological ideas. Lyell announced the theory of the slow development of the structure of the earth's crust. Johannes Mueller had established the physico-chemical school of physiology, Agassiz had collected many of the facts pointing to the theory of evolution, and in 1859 Darwin published the "Origin of Species." Pasteur discovered the organism known as yeast and the relation of germs to putrefaction.

In 1869 Lister announced his method of antiseptic surgery. Helmholtz had published his "Physiological Optics" in 1866, and in 1879 Wundt, his greatest pupil, had established the psychological laboratory in Leipzig, coincident with the beginnings of experimental psychology by James at Harvard. In the very closing years of the last century and the first decade of the present, physics, which in popular favor had suffered a temporary eclipse by biology and psychology, was revivified by the discoveries of Röntgen and Madame Curie, and now disports itself with a youthful exuberance suggestive of the renaissance, while chemistry and all the sciences allied to medicine engage men and money in a fabulous way. In the field of human affairs, we are attempting to apply the methods of science not only to health, but to education, to industry, and commerce, to marriage, religion and government.

To believe that the great economic change of the last one hundred years and the triumphant march of science have been merely coincident, but not causally connected, would be a great mistake. Without tracing in detail this causal sequence, one can get a vivid idea of the relation of the two phenomena by trying to imagine the result of eliminating science and its achievements from our modern life. Out go the electric light, the gas, the gasoline and the kerosene. Our world which now knows no night is plunged half its time into a darkness relieved only by the flicker of tallow candles and burning wood. The telegraph, telephone, and railroad which have shrivelled this earth into a mere fragment of its former size crumble into ashes, and San Francisco moves away from New York ten times farther than it now is. Ocean steamers become sail boats, distancing London from New York fifty, sixty, seventy days instead of six as at present. Instead of eating foods gathered from the ends of the earth, the average citizen is limited to the products of his own locality and to primitive methods of food preparation. Rapid communication between distant places becomes impossible; books and newspapers, few and expensive; common interests and understanding grow more difficult; illiteracy increases, suspicion arises, popular government over wide areas becomes impracticable, and our twentieth-century civilization a fool's dream.

The consequent shrinkage in the wealth of the world would be enormous, our civilization of a surplus would become one of deficit, every class would suffer retrenchment, but most of all the workers, who, by reason of birth, tradition or other limitations, would feel most keenly the scantiness of the world's supply of material goods.

In this perspective we see how science has worked for the liberation of all classes of society. In the long process of civic emancipation it has finally opened the way for the rise of the man who works with his hands. Nor will the former masters of society be willing to cut short the beneficent results of science, for it adds to the pleasure and efficiency

of the rich and high-born as well as of the poor. But it is to the common man that it means most, for it lifts him for the first time in history above the level of economic slavery. Regardless of all the theories of political science and philosophy, this economic liberation of the fourth estate is working toward the ultimate democratization of society with a force as irresistible as gravitation. It matters little what Bourbon statesmen or scholastics may think about ultimate democracy; it matters tremendously that science has made it possible.

The economic results of science are not its only bearings upon democratic tendencies. Equally important are the changes it has wrought upon the attitude which men take toward the world of things. The time was when it was regarded as the surest way to wisdom to retire from contact with the concrete world of change. Plato held that the supreme duty of man is to escape from the sensible world to the world of ideas. The supreme destiny of the philosopher and his fullest satisfactions are to be found in the life of contemplation, culminating in the vision of the good. The world evident to the senses, the world of observation was thus to be disregarded and neglected. It was instable, changing and altogether below the life of reason. Small need, therefore, to examine it, for through it one would never find the truth, the beauty, or the goodness so necessary for the happy soul.

How large a share this doctrine of Plato's may have had in thwarting the development of science in ancient Greece, it is difficult to see. Mr. Schiller thinks it was very great. There were glimmerings of science and the experimental study of nature in Plato's time. Man was recognized as a part of nature; dissections had been practised by the Pythagoreans; the experimental spirit had expressed itself in the attitude of physicians toward their patients; anatomical research had been extended to animals; the relation of the parts of the body to their functions were discovered; Democritus had glimpsed the essence of atomic physics and had practiced experimental demonstration in his teaching; the relativity of nature to human sensibilities was set forth by Protagorus and other Sophists, and attempts had been made by a score of thinkers to analyze the physical world. But it all came to naught. Through the long night between Democritus and Galileo these flickerings of science slumbered.

To the abortion of these scientific interests several causes probably contributed. But if all the others had been removed, the chief philosophy of the time would probably have prevented any wide application of students to the things of nature, for Plato was the one overpowering genius of his time. The dominance of the Greek philosophy down to modern times is coincident with the sleep of science.

To-day all this is changed; we seek the truth through analysis and mastery of the world of sensible observation. The air, the soil, the

lightning, the slime, the refuse of the world, is yielding up the truth by which we live. Your earlier philosopher would escape from the sensuous world; the modern savant eagerly penetrates its depths, making his implements of research as he goes. Compare Thomas Aquinas in an age which rotted with physical uncleanness withdrawing from the world, exalting divine reason above natural reason and refusing the evidence of his natural reason in order to conserve a difficult faith, with Metchnikoff studying the embryology of sponges, the structure and digestion of polyps, and the blood of water fleas to discover the phagocytes, which mean so much for the preservation of human health and the extension of earthly life. To our scientific minds the slimiest, vilest bit of earth may have the truth we need and will hold it forever locked from him who merely sits and thinks. Because this is so, the whole world of matter has assumed a higher value in our thinking than in any age before. To this exaltation of material things all the advances in evolutionary biology and the studies in physiology and experimental psychology contribute. We see now as not before how much is man of a piece with nature, in his ancestry, in his composition and in his future. And we see that the world of matter in which he lives has much in common with himself. Not to escape this world, but to understand it; not to despise it, but to control it, is our modern aim.

In this altered view of the world and man's relation to it, the man who works with his hands has assumed a new status. Both he and his work are objects of general concern, and manual labor that is skilled takes on dignity and honor with the work of the laboratory. No man who has worked with his hands in any of our modern laboratories will long despise his neighbor whose handiwork is in a shop, or in the cab of a locomotive, grimy as that work may be. This world of ours is fast ceasing to be a world of privilege and war, as it long has been, and is becoming through and through a world of work. Faster than he likes the king is being replaced by the scholar, and the soldier is giving way to the engineer. The province of the priest is suffering encroachment by the physician, and the lawyer is having to recognize the contentions of the social worker. In a score of fields the privilege of dogmatism is being crushed by established facts, and the privilege of contempt must more and more disappear as we see how near akin are all the men who work. In the process of our civilization's making, we see that all who labor must share in the glory of the final achievement. In this new view both the worker and his work are lifted to a more elevated place in our view of things. We realize the human value of the work and we see that through his work the worker himself is made.

A third and more subtle relation between science and democracy consists in this, that they are both unwilling to close the books. Neither can accept a closed scheme of thought. Science can not abide a finished

statement of the world; democracy refuses a static law. In the field of animal behavior it is a fundamental fact that the simpler the exciting situation, the more direct is the response. If there is but one thing to do there is but one needed reaction, but if there are two possibilities of behavior there arise conflict, hesitation and compromise. This condition, present as an elementary fact in the behavior of the lowest animal organisms, reaches up through the whole conduct of man, rendering his life a continual struggle to meet the conflicting and incompatible stimulations of his complex environment. The insistent demand for action leads a man to simplify his world as much as possible. Through a maze of facts and forces he seeks one unitary principle. Every complex situation must be simplified, reduced to its lowest terms. When we do this in chemistry we get the atom; in biology we get the cell; in ethics we get goodness; in religion we get faith.

Wherever men have been thoughtful they have tried to secure a simple unitary formula, not alone for the great departments of life, but for the universe as a whole, including the most distant times and spaces, grouping together into a single system the smallest particle of insensible sand and the most mighty divine being. The Weltanschauung, the total world view, the apparent multiplicity of phenomena lost in the unity of eternal forces, this has been the goal of philosophic thinking. The vision of such a picture stirs and satisfies the needs of men because it gives unity to the world and makes for comfortable thought and conduct. To see the completed picture and then deduce one's own relation to it, gives confidence and security amid confusion. But philosophic vision outruns the logic upon which it would rest, and when once a man has announced such a conception he is compelled to spend the remainder of his days constructing the logic to defend it.

The man who would paint a world picture or construct a closed system of thought finds little encouragement in science or among scientific men. The achievements of science have been in the direction of making the world more multifarious than it was. Instead of water we have hydrogen and oxygen, and instead of a human soul we have a streaming concourse of sensibilities, memories, impulses, thoughts, emotions and decisions. Immersed in the swarming concrete realities of nature, the scientist finds it difficult to discover the single unifying idea. Inasmuch as the progress of research is continually laying bare new realities, he refuses to conclude the case, for the evidence is not all in. He has, besides, a half belief that the most important witnesses may be still in waiting. The things which yet lie hidden may overturn his settled beliefs, as the theory of evolution and the discovery of radium have already done. To the uncovering of these hidden truths all the machinery of his craft is devoted. To enrich the already multitudinous world with discovery of as yet unknown facts and forces is his chief aim.

Not that he does not feel the need of a unified world, but he deprecates a unity with half the world left out. The unity which he seeks must embrace it all. If existent he can not see it. If not existent, it may yet be achieved through his and others' labors.

So also it is with democracy. It holds itself ready to give due justice to hitherto neglected interests. For this reason it does not have the stability so advantageous to interests already recognized and established. If one wishes stable government, he can find it in monarchies better than in democracies. Until within the last short while the Chinese citizen knew far more definitely upon what to depend in the way of future wealth or public office than did the citizen of Ohio. The lineage of his parents and their wealth, and the inescapable doom of sex, prejudiced his whole future within very narrow and definite limitations. For four hundred years the firm grip of Manchurian power, abetted by a religion which emphasized the virtue of tradition and the established order, gave China a government which for stability has seldom been equaled. During the same period the more democratic western peoples have seen turbulence, transition, and constant shift and change of policies.

Nor is the democratic state always the most efficient state. Let the German emperor conceive that the future German Empire is dependent upon particular forms of education and particular humanitarian movements, and he can by virtue of his concentrated power effect the necessary changes in a brief time. The single man can move more swiftly to the achievement of a clearly conceived end than can a whole people be brought up in response to the prophet's vision. It is because of this that Germany in a generation has accomplished industrial, educational, and social changes which would have required much longer if they had been the work of the whole population of the German Empire.

But whatever sacrifice of stability and efficiency must be made the democrat is willing to make in the interest of a larger end. That end is the possibility of forcing to the front interests which the existing government does not recognize. If he wishes to add to his governmental machinery a new instrument, such as preferential primaries, the income tax or universal suffrage, he does not want the way too effectually blocked. Just as men in the sphere of thought refuse to construct a closed system, so do they in the field of government refuse to make their laws and constitutions too rigid, or their public officers too secure in their positions. They want their government fluid and responsive to change, for the moral issues of life are as surely in a process of development as are the intellectual ones. To fix a government on the basis of the moral ideas of 1789 is as repugnant to the man who thinks as to write a natural history in the year 1913 with the theory of evolution left out. Just as certainly as the century has widened our vision of the

world of matter, it has also brought to light moral facts, and problems unknown to the framers of the American constitution. In order that these newer living issues may have their day in court, the democrat is willing to tolerate a less fixed and stable government than is your cavalier, your tory, your man of comfortable surroundings who doesn't like to be disturbed.

Further, we are coming to see that the flexible government is not dangerous, that we may move on to a larger justice easily and smoothly without imperiling the goods we already have. That this new vision is becoming real to us is due to two causes. One of these is our experience in undergoing political changes; the other is our experience with science. Science is not destroyed by new discoveries and inventions. Radium and bacteria may alter certain highly important hypotheses, but they do not destroy our faith in science or make it a less serviceable instrument to men. It has become quite a matter of course to expect revolutionizing discoveries, and science is at heart disposed to readjustment and revision. This attitude has taken hold of the general social mind through the popularization of science, and society at large has acquired a faith in a mobile, growing body of truth. It is probably true that twentieth-century society has no more vital faith than this, and it would be strange if it had not affected our ideas of government and politics.

For the infusion of scientific conceptions into other fields of thought we are not without splendid precedent. President Wilson has shown how the American constitution was a reflection of the prevailing Newtonian physics, and all of us know how thoroughly the concept of evolution has interwoven itself into every specialized department of modern thought. In like manner, the growing receptivity of men's minds to new interests in society, to the rights of the laboring classes, to the claims of dependent peoples, to the widening interests of women and children, has been greatly accelerated by the diffusion of science and scientific ways of thinking. Men have become accustomed to changing their minds, to having their beliefs unsettled, to feeling the good that comes with a new order of things.

Finally, and in the most subtly penetrative way, the kinship of science and democracy appears in their attitude toward the future. To both, the present is but a cross section of an advancing stream whose source is in a distant and indefinite past, whose current has gathered momentum in its progress hitherward and which is pouring itself into the future with a rapidly accelerating force. To neither is the past of this stream so interesting or important as its future, and the present is but a point of vantage for the movement forward. There is a type of mind to whom this way of thinking is difficult or even offensive. To it the good things were the possession of former peoples, and to those

earlier wisdoms and virtues the modern reprobate may hardly attain. Such is the theological mind, whose vision of the truth is a distant and completed revelation; such is the legal mind which judges a current moral problem wholly by the legal precedents. The one hallows the ten commandments; the other glorifies the constitution. Of such mind are we all when we uncritically accept the conventions of our group or yield thoughtless obedience to the traditions of our race. To capitulate to custom or resign ourselves to habit is to accept the past as virtuous and final.

Against this view of the world both science and democracy resolutely oppose an exuberant faith. The bulk of men is wiser and better than it has ever been; it can be infinitely better and wiser than it is. The critics of science have gratified themselves in pointing out the limitations of its method. But science replies by pushing those limitations further back. The whole achievement of experimental psychology has been made against the settled belief on the part of many that it could not be done. Twenty years ago it seemed that physics had finished its task. There was then a pessimistic feeling that all the interesting things had been discovered. To-day men are undertaking experiments that would have been thought fantastic at that time, and the undiscovered territory seems greater than ever. They said we could not fly, but Professor Langley and the Wright Brothers did it. They said you can not predict the weather, but we can tell it a week ahead of time. Once it was thought a miracle to cure the blind, but now we do it every day. Once disease was regarded as the visitation of an offended god, but to-day we meet it and destroy it with the instruments of science. Once insanity was the evidence of evil spirits, but to-day the legion of devils is put to flight by medicine and psychology. Once marriage was regarded as a holy ordinance to be approached in the spirit of religious humility; to-day its holiness depends in part upon its religious sanctions; it also depends upon its effects upon possible posterity as these are indicated by biology and pathology.

Nor is your individual scientist confused or disheartened when you point out to him how science fails in hosts of cases. He knows that aviators fall, that the weather does not turn out as predicted, that there are far more diseases for which we do not know the cure than there are of those for which we have an antitoxin, that there are forms of insanity that are supposedly incurable, that we do not know all the laws of heredity, that the subtle processes of human thinking and education are baffling to our present psychological methods. But he is not a pessimist. He is one of an advancing army, and he believes that all about him there are the solid achievements of the campaign; points have been taken and citadels have been established back of which the forces of science will never need to retreat. That many of the supposed con-

quests of science have been found unsound and that the still unpossessed territory is illimitably greater than that already gained is but a challenge to his courage and his resources. To the truly scientific spirit science is in part an achievement; in a larger sense it is a hope, an aspiration, a kind of intellectual idealism. As prophecy it is more convincing than revelation; as a field for constructive imagination it is as interesting as poetry or music.

This also is the spirit of democracy. If one insists on regarding society as a completed thing, then it must be admitted that democracy does not justify itself. It has never yet established on a lasting basis that thoroughgoing equality of which it dreams. The so-called democracy of Greece was admittedly founded upon the institution of slavery; that of England rests upon an economic submergence of large masses of its people, and in our own country privilege in business, politics, education and religion, with the consequent corruption of society and abortion of justice mocks our praise of democracy even while we make it. Our enemies need but to uncover the facts to lay bare a frightful indictment of our claim that democracy is the best form of social organization. City councils bought with money, weak and incompetent mayors, police forces subdued by threats or seduced by gifts, legislatures the willing servants of men who want the law shaped for their private gain, governors caught in the clutches of the party machine and unable to perform their sworn duty as executors of the law, seats in the senate bought with money or the promises of preferment, retired congressmen delivering their information acquired in the public service to private wealth for private ends, public courts shaping their procedure so that the man of means has an advantage over the poor man in the administration of justice, the supreme court of the land erecting itself into a law-making body through constitutional interpretation and thereby overriding the wishes of the people as expressed through their legislatures; four million laboring men subsisting on incomes below the level of a living wage; children sacrificed to factory labor; women unable to secure from state legislatures labor conditions comparable to those of men; the dispensation of religion administered in such a way as to make the rich comfortable and stupid, the poor indifferent or bitter, and the thoughtful anti-ecclesiastic; education for the professional classes but little for laborers; palaces and leisure for the rich and hovels and drudgery for the poor these are the facts flaunted before us in this most democratic country in the world.

But the real democrat is not disheartened by the hideous picture. He sees all this and he sees beyond it. In the presence of many failures he discerns one success, and to him that success is the important thing. You show him a score of corrupted cities, and beyond them he sees Cleveland with its new charter; you show him the terrible conditions

of the textile and steel workers and he thinks of the workmen's compensation and state insurance laws; you show him a score of state governors subservient to the pressure of wealth and he recalls Johnson and La Follette; you show him failures in government ownership and he thinks of the post office and Panama Canal; you talk of aristocratic churches and he remembers the Salvation Army and the institutional church; you mention subsidized education, and he thinks of the state university; you recount the multitudinous cases where the popular suffrage fails to select men of learning and character and he thinks of Hughes, Roosevelt and Wilson.

That the upward strivings of democracy should have issued in innumerable abortions of social ideals is what on his theory was to have been expected. That these same strivings should have brought to maturity one well-born child of promise is much more significant, for it is the augury of the future. Not the level of his attainment but the direction of his going, concerns him most. His faith in democracy is not a doctrine of comfort; it is one of effort; he believes not so much in something attained as in something attainable. It is not something to be preserved, but something to be achieved. Just as science is an intellectual aspiration, democracy is a moral aspiration. Together they constitute an idealism toward which the will to live strives with an ever-increasing measure of success. To get the tinge of this idealism is to have one's fragmentary work become more vital. The isolated research and the little extension of justice in the affairs of men become significant by their association with larger movements. These in turn grow weighty with the wider purposes of many men and distant times.

In the realist sense, therefore, our modern life is typified by the twin movements of science and democracy. To our aspirations they give hope; to their achievement they solicit all that is vital and generous in men. They front the future not with the fatalistic view that somehow all will turn out well, but with the settled faith that that future will be made by what men do. Both are militant movements. They set a world of problems still unsolved and lay upon men the obligation to find the way. In their behalf they enlist a number of social forces, but to be the leader in their militant campaigns the call comes loudest to the university. Sad will it be if its ears are closed with selfish pursuits or its feet heavy with an unforgettable past.

BIOLOGICAL EFFECTS OF RACE MOVEMENTS

By Chancellor DAVID STARR JORDAN
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THERE are but three ways in which the force of a race or a nation may be permanently lowered: (1) Emigration, the transfer of stronger elements to other regions; (2) immigration, filling up the gaps with people of lower native ability or energy; (3) war, the destruction of the virile and soldierly.

Emigration has played a large part in the depletion of peoples in different districts of Europe and even in older sections of the United States. This may mark a loss to the particular region involved, but none to the world, the value of a man and his posterity, broadly speaking, being as great in one place as in another. Moreover, the pioneer gains by travel, picking up something on the road, though he may also lose through separation from the framework of society. In the new freedom he tends to fall out of touch with the achievements of the old social fabric. Much of human effectiveness consists in entering into the work of others. But, on the other hand, the pioneer will escape many hampering traditions, and the sturdiness of racial stock is in no way dependent upon culture, the social values of native strength reasserting themselves when opportunity offers. Meanwhile, the gains in the new world may be traced as losses in the old. For example, from the counties of Devon and Somerset arose, primarily, the colony of Massachusetts Bay. From the loins of Old England, New England arose, and from self-governing New England, the democracy of the United States. From Devon especially came forth the Puritan conscience, most precious political heritage of the republic. Under its influence every public act finds its final test in moral standards. Such standards still rank more highly in America than in any other land. The American people may consent to unrighteous deeds under the impulse of falsehood or greed, but only for a time. They make many mistakes in the rush of events. They may apply standards wrongly, but, if they do, the case comes up again for settlement until at last it is settled rightly.

By *immigration,* lands scantily occupied by barbarous races have been replaced by peoples more efficient or more aggressive. Through the same agency strong nations have sucked in weaker groups to fill the vacuum caused by war or to meet the demands of industry. The history of America, North and South, has furnished examples of all these. Through conquest by war as well as out of industrial needs grew up the

institution of slavery. In Rome, "whole tribes were borrowed" for the work of agriculture, while conquered groups were utilized as menials or slaves.

Everywhere, under these conditions, the blood of the slave or the conquered has diluted that of the dominating race, usually to its detriment. For example, in most Spanish and Portuguese colonies Latin blood has been mixed with the aboriginal, producing crosses showing few of the virtues of the European stock. Indeed, in Portugal, the mixture from subject races in Brazil, Africa and India, has invaded the parent itself to its social and political confusion.

Two main facts appear in this connection. In many racial crossings occurs the mingling of the least desirable types of each. Naturally where the dregs of one race mix with the offscourings of another arise distressing possibilities of vice and incompetence. For instance, the Eurasian in Asiatic sea-ports "is damned from his birth and on both sides." But when good European blood mingles with Asiatic strains as good, there is no evidence that the progeny is inferior to either parent stock.

The words "hybrid" or "mongrel," terms of reproach as usually applied to the human race, relate commonly to the union of widely different peoples. But the question of "race or mongrel" can not be settled by *a priori* assertions as to superiority of pure over mixed races. There is no general law that mongrels are sterile, inert and non-resistant. It is a matter to be determined in any individual case of crossing by a study of the results derived. Experiments of the sort have no pertinency unless best is mated with best, and even then they might prove conclusive only if many times repeated. And no result shown in individuals need be valid as a general law of crossing. It would apply only to the particular types in question. No important information could be expected from the study of the first generation. One would need to know the nature of the recessive characters involved as well as of the dominant ones. The final Mendelian disposition of mixed race characters must determine the final answer.

The intermarriage of European races can hardly be called crossing at all, as the racial differences concerned are of slight order, little more than temperamental at the best, and most of the traits we commonly recognize are matters of education. All those qualities which disappear in a generation in America must be chargeable to education, not to race. And, in general, other things being equal, the advantage seems to be on the side of the blended races which belong to the same general stock. Moreover, in civilized lands, there are only blended races. Blending is part of civilization. Pure strains confined to isolated islands or valleys, thus withdrawn from competition, by no means represent the best of any race. There is no wide-spread race which is pure. There is no such

thing as a pure-blooded German or Frenchman. "Norman and Saxon and Dane are we" of England. Likewise are we Briton and Welsh and Cornish; also Scotchmen, Highland and Lowland, Manxmen, Ulstermen and Irishmen.

That the crossing of the closely allied European races in America has, of itself, brought no disaster to our republic is a matter of visible observation. That wide crosses necessarily work always for evil is not proved. Apparently the mulatto in America, as a whole, is superior to the pure African negro. And the ultimate fate of the negro race in America is apparently to become mulatto, even though the introduction of white blood is relatively much less frequent now than in the days of slavery. But, in all these matters, we are much in need of scientific, that is, exact and systematized information.

However, it can be clearly seen that the introduction of black blood has not been a gain to the republic. And we may also admit that much of our later immigration from Europe and Asia has lowered our own average. The original impulse to America was that of escape from paternalism and oppression, two words for the same thing. America was a haven of refuge from senseless tyranny. Immigration thus brought to the new world a wealth of initiative and adaptability, such as no nation ever inherited before. But in later days this current has changed. Wider opportunity has opened before the common man in the more progressive nations, and the incentive of freedom has been less acute. Moreover, while still "America means opportunity," this is not always to be had for the asking.

The demands of manufacturers, the operations of steamship companies and the possibilities of earning money without economic freedom, and later, the ruinous cost of war are drawing another type of immigrant from other parts of the world. Among the immigrants of to-day there are some with magnificent personal possibilities, men of the stuff that makes republics. But most of them are not such, and, while their presence adds to our material wealth, they constitute, as a whole, a burden on our democracy. Only a man who can take care of himself and have something left over for the common welfare is a good citizen. It is hard to maintain the principle of equality before the law among people who have never felt and never demanded such equality.

The claim is sometimes made on an assumed basis of science, that all races of men are biologically equal, and that the differences of capacity which appear are due to opportunity and to education. But opportunity has come to no race as a gift. By effort it has created its own environment. Powerful strains make their own opportunity. The progress of each race has depended on its own inherent qualities. There has been no other leverage. Physical surroundings have played only a minor part. To say that one race as a whole is inferior to another is only to

repeat what is said every day by individual men. This does not imply that the lower man or the lower race need be robbed, enslaved or exterminated. Nor that a lower race may not produce its own prophets or scholars or heroes. The tribe of Australian bushmen is counted one of the lowest on earth. Not long ago I met in Adelaide, a full-blooded "Black-fellow," broad-minded and competent, a mechanical engineer by profession, a man who would hold his own in any community. That race is lowest which shows, on the whole, least capacity for self-elevation. "All men are born free and equal," it is asserted, but such equality is political only. It can not be biological. In every race are certain strains having capacities not attainable by the mass. There should be equality of start, equality before the law, but there will always be differences of attainment. The gifts of potentiality, unit characters of the germ-plasm, are not shared by all people of the same race. The average status of one may be below that of another, and the highest possibilities of one type may be greater than that of another. In general, the highest range of possibilities in every field has been reached by the "blonde races" of Europe. Groups of less individual or of less aggregate achievement may properly be regarded as "lower."

NATURAL SCIENCE IN THE MIDDLE AGES

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PROBABLY ninety-nine out of every hundred educated persons would be surprised to learn that there was any such thing as natural science in the middle ages. Lest I seem to impute too much ignorance to my present audience, perhaps I should lower the ratio to nine persons out of ten. That is really a flattering estimate, since one of the most recent works on the middle ages, Taylor's "The Medieval Mind," while it devotes two volumes to monasticism, scholasticism and other features of medieval thought, treats of natural science in the middle ages only incidentally in two chapters upon Albertus Magnus and Roger Bacon, and dismisses all other medieval students of nature with the words,

> Assuredly, through all the middle ages there were men who noticed such physical phenomena as bore upon their lives, even men who cared for the dumb beginnings of what eventually might lead to natural science. But they were not representative of their epoch's master energies.

Such an attitude is due partly to the fact that the history of science has as yet been little investigated; it is also partly due to misconceptions concerning the middle ages. If we appreciate what the middle ages really were, we shall not be amazed to find an interest in natural science then.

Every one knows that by the term "middle ages" is roughly indicated the period between ancient civilization and modern civilization, or, more specifically, between the decline of the Roman Empire and the Italian Renaissance or the discovery of America. For a time historians, under the influence either of classical or of Protestant prejudices, seemed to think that between ancient civilization and modern civilization there was no civilization. Therefore, the term "dark ages" was applied to the middle ages. Everything worth while in modern life was supposed either to have been rescued from the ruins of antiquity by the men of the Renaissance, or to have originated at some time since. Every disused and decadent idea or custom which modern men threw away on to the historical ash-heap was designated as medieval.

But after a while the middle ages were studied more thoroughly and sympathetically. Monasticism, feudalism, scholasticism, the social and

industrial groups of manor and guild, the crusades, the pilgrimages, the friars, the cathedrals, and the great ideals of the church and of chivalry, were recognized as important in human history, though different from the thoughts and doings of men before or since. The expression "medieval civilization" was now introduced alongside of "ancient civilization" and "modern civilization," while the phrase "dark ages" was restricted to the early middle ages while the barbarian invasions were going on. Indeed, a recent writer on the history of education wittily states that successive investigations keep pushing the "dark ages" so much further and further back that they will probably ultimately cover no time whatever.

There was, then, civilization, if not natural science, in the middle ages. But it would be leaving a wrong impression to imply that medieval civilization was something quite distinct from ancient or modern civilization. The fact is, and after all it is just what one would naturally expect, that medieval civilization was in large measure a combination of ancient and modern elements. Much it inherited; much it originated; and much it passed on. Moreover, the middle ages really belong partly to ancient and partly to modern times. This principle is now being largely accepted even in high-school teaching and text-books. The year course in ancient history is carried down to Charlemagne, while medieval and modern history are united as a single year's work. In the museums of Europe, too, no great gap is observed between the middle ages and the renaissance, but objects are usually classified together under one caption as of both those periods.

It is very difficult to separate history into distinct periods, yet there is considerable reason for regarding Charlemagne, towering as he did seven feet tall and fighting a campaign every season for over forty years, as the last great landmark of ancient times. With all his vigor he caused little or no permanent progress. He failed to drive the Mohammedans from Spain; under his successors the Northmen and other invaders broke up his empire. But when the Northmen, after their wonderful expansion in all directions from Greenland to the Mediterranean and from Russia to North America, had settled down in Normandy, England, Sicily and elsewhere; when they had with amazing rapidity adapted and improved upon such civilization as they found still existing in their new homes; when the Arabs had brought from the East to Spain the material civilization of the Orient and the intellectual treasures of the Greek genius; and when the men of the north, either as peaceful traders and pilgrims or warlike crusaders, had visited Spain, Constantinople and the Holy Land; the wheels of progress started moving with a new alacrity and things began to hum. Once again, as had happened before in the Mediterranean Basin, the races of the north descended upon and fused with those of the south, and the east passed on to the west the torch of civilization.

The results of this contact were felt first in Spain and Italy, but the new civilization became generally manifest throughout western Europe in the twelfth and thirteenth centuries. This is the period of which I shall speak this afternoon, and I shall now remind you of some things in the twelfth and thirteenth centuries that were modern in character, so that you may not be surprised when I suggest that modern science, too, began in the middle ages. A book has been written recently on what we owe to the Greeks; let us see what we owe to the middle ages.

In the first place, the Celtic and Teutonic races and the Roman Catholic church. Those races were absorbed, and were trained and inspired to erect a new civilization. In this work the church, as the greatest social force of the times, played the chief part. It has well been said that the Teutonic vigor and originality, and the spirit of western Christianity were quite as responsible for the Italian Renaissance as was the classical revival. There was no renaissance at Constantinople, though there was plenty of study of Greek there. At Constantinople classical culture remained as it were in cold storage. In Italy there was a fresh living movement. New blood and new ideals were responsible.

Secondly and more specifically, our modern languages and literatures began in the middle ages before the classical revival. Already in the twelfth and thirteenth centuries the languages of modern Europe were taking on literary form, and poets were expressing in their own tongues the spirit of a new age. A specialist in comparative literature assures us that the popular literature of the twelfth and thirteenth centuries resembles eighteenth and nineteenth century literature more than it does that of the ninth and tenth centuries which were so much nearer in mere point of time.

In art we owe to the middle ages the marvelous Gothic style of architecture with its new structural conceptions and infinite resource of adornment.

In politics there began then national states in contrast to the city states and empires of antiquity. Representative government, too, was developed as it had not been in ancient times. Representative institutions were widespread in western Europe at the close of the thirteenth century, and survived in England through succeeding centuries to furnish a model for other nations which reintroduced parliamentary government in the nineteenth century. Bishop Stubbs limited his famous "Constitutional History of England" to the medieval period. During that time the English were busy making their constitution; ever since they have been busy breaking it.

The middle ages recovered from the economic dry-rot which had ruined the Roman empire from within before ever the barbarians broke through its military shell from without. The middle ages revived the

city life of antiquity, but with these modern differences, that religion was separate from the state, and that the institution of human slavery found no place in the medieval town. There the freeman was not ashamed to toil, and the runaway serf could acquire liberty. Slavery has been reckoned by one historian of science as one of the five great obstacles to the advance of science in antiquity; if so, the middle ages were better off in this respect.

Early in the twelfth century there was a great outburst of enthusiasm for learning and of intellectual curiosity. Students swarmed from all parts of western Europe seeking teachers; the result was that foundation of the European universities whose intellectual life has been continuous from then until now. Roman law was revived and studied scientifically. The fruits of Greek philosophy, preserved by the Arabs in Spain or the Orient in translations and commentaries, were translated again,—this time into Latin, which in the Christian West was now the universal language of scholarship. Humanism, classical scholarship in the strict and narrow sense, and the great paintings and sculptures of the Italians in the fifteenth and early sixteenth centuries, were but later phases of the same movement. Petrarch, the first great humanist, who adored Cicero, wrote letters like Pliny the Younger, collected and copied ancient manuscripts, and came to scorn all contemporary interests except his own fame, has often been called the first modern man, but in many ways seems a reactionary looking backward. Abelard, the first great schoolman, who over two centuries before Petrarch's time wandered forth from his native Brittany, first seeking teachers, then triumphing over them, then attracting students to himself; Abelard, who dared to show that even the church fathers held conflicting opinions, and who advocated sceptical and systematic criticism as the best road to knowledge; Abelard, more than Petrarch, deserves the title of the first modern man.

Turning now from medieval civilization as a whole to this medieval learning in particular, let us correct some erroneous notions concerning it. For one thing, we have been taught to call medieval learning scholasticism, and to think of it as concerned almost exclusively with logic, metaphysics and theology; while we have been taught to associate the beginnings of modern science with the Italian Renaissance. But the fact is that the narrow humanist of the Renaissance took no more interest in natural science than did the narrow schoolman of the middle ages. The sciences which they cultivated were philology and theology. The fact is that natural science has had a more or less continuous development of its own, largely independent of the middle ages and Renaissance. Books on nature written in the twelfth and thirteenth centuries were still satisfactory to readers in the fifteenth and sixteenth centuries, as is shown by numerous editions of them which were printed then.

The reliance of the middle ages upon the authority of the Greek

philosopher Aristotle has often been exaggerated. In medicine they recognized Galen as a greater authority than Aristotle. In astronomy Ptolemy was their guide. In natural history they cited Pliny the Elder. Indeed they used scores of other authorities than Aristotle. But had he been their sole source of information, they would not have been without interest in natural science, for Aristotle devotes much attention to that field. He wrote not only on logic, ethics and metaphysics; but on physics, animals, plants, minerals, the heavens, sleep and waking, generation and corruption, and so forth. Indeed, he was without much doubt the greatest scientist of antiquity.

Now the twelfth century had known only Aristotle's "Logic." When his other works were brought from Spain and translated from Arabic into Latin in the early thirteenth century, those devoted to nature created even more of a *furore* than the others. The great University of Paris at first prohibited these newly discovered books in natural philosophy. But it was impossible to check the rising tide of secular and scientific learning. Another French university at Toulouse advertised its readiness to teach these works of Aristotle on nature, and before long the forbidden books were being freely taught at Paris itself.

Paris's two leading theologians and commentators on Aristotle were also recognized in their own day as great students of nature. Albertus Magnus wrote on all the subjects that Aristotle had treated and added much new information in his works on plants and animals. Thomas Aquinas is usually thought of as a theologian; but when he died, the University of Paris wrote to the Dominicans asking that his bones might be sent to Paris for burial, and also requesting the transmission of some books begun by him while at the university but not as yet completed upon his departure from Paris. What were these writings; theological treatises, commentaries on the minor prophets, or manuals of devotion? None of these. They were a commentary on the philosopher Simplicius; another on Aristotle's treatise "The Sky and Universe"; a third on Plato's "Timæus," a dialogue dealing with nature; and finally, a treatise on irrigation and mechanical engineering.

Another erroneous notion concerning the middle ages is that nature was studied chiefly in order to illustrate spiritual truth or to teach moral lessons. The "Bestiary," a little manual about animals used by the clergy for illustrations in their sermons, is often referred to as typical of medieval science; but one might as well judge modern science by the lurid articles in the supplements of our Sunday newspapers. Far more typical are the long encyclopedias in Latin prose which collected all available information concerning the phenomena of nature, and whose motive was rather a keen curiosity about the things of this world than a desire merely to illustrate divine verities. It is true that one of the earliest and briefest of these encyclopedists, Alexander Neckam, an

English monk, still tends to moralize and allegorize. For instance, he says that some persons call the spots on the moon caverns or mountains, but that he believes that they were put there to signify the stain of sin which Adam's transgression brought into the world. But Neckam also displays a scientific attitude. When he finds a statement in the book of Genesis in apparent contradiction to the astronomy of his time, he explains that the Bible here follows "the judgment of the eye and the popular notion," but that astronomy is really right. The later and longer encyclopedias of Arnold of Saxony, Thomas of Cantimprè, Bartholomew of England, and Vincent of Beauvais greatly increased the amount of space devoted to nature and contained comparatively little moralizing.

I may explain that in a medieval encyclopedia, instead of the alphabetical arrangement followed in modern encyclopedias, there is first a topical arrangement under such heads as Reptiles or Birds or Trees, and then an alphabetical arrangement under each topic. As in modern encyclopedias, most of the information was taken from other books, but sometimes the medieval encyclopedist adds new data which he has heard from hunters, travelers and others, or which he has learned from personal observation.

The twelfth and thirteenth centuries were a period of intellectual curiosity. Albertus Magnus says that he lists the properties of individual plants in order to satisfy the curiosity of his students. A favorite book of the period, translated into almost every European language, was entitled, "De omni re scibili et quibusdam aliis" which may be freely translated as "Concerning everything that can be known and then some." Indeed, it is not merely in professedly learned works written in Latin that one sees the interest of those times in natural science. If we turn to popular literature in the tongue of the layman and open one of the long French romances of the thirteenth century, we find Dame Nature making a speech concerning various branches of natural science which occupies a considerable section of the entire poem, whereas little space is devoted to logic or theology.

This interest in nature is often accompanied by an independent scientific spirit, of which we have just seen some evidence even in the moralizing Neckam. But it can be traced back earlier than him to the beginning of the twelfth century. As the life story and writings of Abelard illustrate the great interest in logic, philosophy and theology at the beginning of the twelfth century, and help to explain the origin of the University of Paris; so the career and books of a contemporary of his with a very similar name, Adelard of Bath, depict a pioneer of natural science. As Abelard went forth from Brittany through the towns of France in quest of Christian teachers, so from England Adelard made a wider circuit in lands both Christian and Mohammedan, where he might acquaint himself with all that was best in contemporary learning, but especially in mathematics and natural science.

In one of his works he tells us that upon his recent return to England after long study abroad, his nephew and other friends urged him to disclose some of the new ideas that he had learned among the Arabs. The result is his treatise called "Natural Questions" in the form of a dialogue with his nephew, who proposes, by means of a set of questions, to force his uncle Adelard to justify his preference for "the opinions of the Saracens" concerning nature over those of "the schools of Gaul" where the nephew has been studying. Adelard agrees to this, but wishes to state at the start that, because of the prejudice of the present generation against any *modern* discoveries, he will attribute even his own ideas to the Arabs and will not be personally responsible for what he says. "For I know," he declares, "what misfortunes pursue the professors of truth among the common crowd. Therefore it is the cause of the Arabs that I plead, not my own."

Adelard's use of the word "modern" should be noted. The word *modernus* is not found in classical Latin, but is often employed in the twelfth and thirteenth centuries. In another passage Adelard distinguishes "the writings of men of old" from "the science of moderns." Bartholomew of England rejects an astronomical theory of the Venerable Bede, and says that he prefers the view of "modern writers who, as I think, have scrutinized the subtler signs of philosophy more profoundly." Peter of Spain, who finally became Pope John XXI., in one of his medical treatises states his sources of information as "ancient philosophers" and "modern experimenters." Several other writers use like expressions. So perhaps Adelard rather than either Petrarch or Abelard should be called the first modern man.

The opening question asked of Adelard by his nephew is, "How can plants grow from earth which they so little resemble?" The nephew fails to see how this can be explained except as "a marvelous effect of the marvelous divine will." Adelard retorts that no doubt it is the Creator's will, but that the operation is also not without a natural reason. This gives a fair example of the tone of the dialogue throughout; Adelard upholds scientific argument and investigation against a narrow religious attitude. He insists that he is in no way detracting from God, whom he grants to be the source of all things, but that nature "is not confused and without system," and that "human science should be given a hearing on those points which it has covered." He also sets reason above authority; and sharply reprimands his nephew for following authority as if he were a brute led by a halter, for his bestial credulity, for his trusting simply in the mention of an old title. In fine, he tells his nephew that if their discussion is to go any further, he must drop authorities and "give and take reason." He assures his young relation that he is not the sort of a man "who can be fed on the picture of a beefsteak."

It is true that both questions and answers in this pioneer book of natural science are usually more amusing than instructive to the modern reader, although Adelard in his prologue says that he is sure his treatise will be useful to his hearers, but not that it will prove entertaining (tractatum . . . quem quidem auditoribus suis utilem fore scio, iocundum nescio). Asked why men do not have horns, Adelard first objects that the question is trivial; but when the nephew urges the utility of horns as weapons of defense, Adelard replies that man has reason instead of horns, and that, as a social as well as bellicose animal, he requires arms which he can lay aside in time of peace. Asked why the nose is placed above the mouth, he replies that it serves the head while the mouth serves the stomach. Many of his explanations are grounded upon the hypothesis current since the Greek philosopher Empedocles, that all nature is composed of four elements, earth, air, fire and water, and characterized by four qualities, hot, cold, dry and moist. Thus when Adelard is asked why bright students often have poor memories, he answers that a moist brain is conducive to intelligence, and a dry cerebrum to memory. He explains his nephew's weeping for joy to see his uncle safely returned from the Orient by the theory that his excessive delight heated his brain and distilled moisture thence.

But reasoning from a general theory of nature to explain particular phenomena is not Adelard's sole method; he also relies on experience. Nor are all his notions crude and incorrect. While he accepts the long established theory of four elements, he is careful to explain that the earth which we see and call by that name is not the element earth, and that no one has ever touched the element water, or seen the elements fire and air. Every particular object contains all four elements, and in daily life we deal only with compounds.

Adelard states the eternity of matter as follows:

> And certainly in my judgment nothing in this sensible world ever perishes or is less to-day than when it was created. If a part is dissolved from one union, it does not perish but is joined to some other group.

When his nephew asks him to explain the working of a magic water jar which they once saw at an enchantress's house, and which had holes in both top and bottom so that the attendant could check the flow of water from the bottom by placing his fingers over the apertures in the top, Adelard accounts for the trick by saying that nature abhors a vacuum. Asked how far a stone would fall, if it were dropped into a hole which extended through the center of the earth, he states that it would fall as far as the center and stop there.

We have heard Adelard upholding scientific argument and investigation against a narrow religious attitude. This position is further illustrated by a contemporary of his, William of Conches in Normandy. William, too, complains that the age is instinctively hostile to new

ideas; and dilates upon the unreasonableness of those persons who are unwilling to listen to explanations of the natural phenomena mentioned in the Scriptures, but prefer to accept them blindly. He declares that since they themselves know nothing of the forces of nature, they are unwilling that any one else should investigate these. "We, on the contrary," he says, "think that a reason should be sought in every case, if one can be found." In another passage William's indignation is aroused by those who say, "We don't know how this is, but we know that God can do it." "You poor fools," he retorts, "God can make a cow out of a tree but has he ever done so?"

This theological opposition, of which Adelard and William are conscious, brings before us the important problem of the attitude of the medieval church to science. There is not time to-day to argue it at length; I can only give you my conclusions. We see science establishing its own standpoint and marking out the boundaries of its realm. The first surveyors, like Adelard and William, naturally meet with opposition and encounter a jealous attitude which fears lest study of science and nature will be at the expense of religion and God. But in the end it turns out that so long as they do not trespass upon the particular preserves of theology their stakes are not pulled up. In the course of two centuries the church gradually gets used to science, just as the University of Paris finally accepts the new Aristotle. By the middle of the thirteenth century Thomas Aquinas, from whom we expect an authoritative presentation of the position of the church, holds that to a large extent the fields of theology and natural science are distinct; that theologians should not try to settle purely philosophical or scientific problems, and, conversely, that every theory of ancient philosophy or scientific hypothesis is not to be regarded as a religious dogma.

Men of science, who were often clergymen themselves, seldom attacked Christianity in the middle ages, and as a rule maintain the usual medieval tone of respectful and devout feeling toward theology and religion. Conversely, there seems no adequate proof for a single specific instance of persecution of men of science by the church for purely scientific views in the twelfth and thirteenth centuries. The occasions when such men got into trouble and when we know the reason why, are just those occasions when they left science to dabble in theological or ecclesiastical concerns. Roger Bacon has often been pictured as a long-suffering martyr to the cause of science, but this is a legend constructed from historians' imaginations and added to by successive writers; the sources indicate that he was imprisoned only once, and then we do not know for how long nor whether his scientific work had anything to do with it. On the other hand, many cases might be mentioned where popes and prelates patronized and protected medieval men of science, while Peter of Spain became pope himself.

It can not be shown then that there was bitter warfare between science and theology in the middle ages; nor, on the other hand, was science a handmaid at theology's beck and call. The two interests were beginning to separate, sometimes with a little friction, often with much caution on the part of science, yet on the whole with maintenance of friendly relations between them. Science was still somewhat under the wing of the church, but science was learning to use its own wings.

Having traced back the scientific spirit in western Christian Europe to the twelfth and thirteenth centuries rather than to the time of the Italian Renaissance, let us now examine some of the particular fields which it investigated.

Physics was studied now, and not merely along the theoretical lines of Aristotle's treatise. Further progress had been made among the Arabs in optics; and the subjects of vision, perspective, reflection and refraction were now better understood than in the time of Ptolemy. The men of the thirteenth century speedily absorbed these new ideas of the Arabs. Roger Bacon, it is true, while according due credit to the Arabs, gives us the impression that his Latin contemporaries were neglecting the subject of optics, and describes the formation of rainbows, and the characteristics of convex and concave mirrors, burning glasses and lenses by which the size of objects can be greatly magnified, or mirrors by which their numbers can be greatly multiplied, as if all these things were marvelous novelties. Bacon's own discussion of these matters is excellent, and in some details he corrects or adds to his Arabian authorities, but he does not do justice to his Christian contemporaries. At just about this time Witelo, a Pole who traveled in Italy, wrote an important treatise on optics in which he embodied the views of Alhazen, the leading Arabian authority, together with many additions from other writers and of his own. Moreover, the French "Romance of the Rose," probably written soon after Bacon's work, shows remarkable familiarity with all the things that he describes. Of rainbows it remarks that

> Only he who's learned the rule
> Of optics in some famous school
> Can to his fellow men explain
> How 'tis that from the sun they gain
> Their glorious hues.

The author also mentions burning-glasses and various other sorts of mirrors, but he refers to all these as well-known scientific facts, and says that there are plenty of books about them. He also unmistakably describes magnifyng glasses when he tells us that from optics one

> . . . may learn the cause
> Why mirrors, through some subtle laws
> Have power to objects seen therein
> (Atoms minute or letters thin)
> To give appearance of fair size,

Though naked unassisted eyes
Can scarce perceive them. Grains of sand
Seem stones when through these glasses scanned.

The poet goes on to say that through these glasses one can read letters from such a distance that one would not believe it unless he had seen it. Then he concludes,

But to these matters blind affiance
No man need give; they're proved by science.

From the testimony of several other contemporaries we know that eye-glasses had been invented before the close of the thirteenth century.

Another important physical treatise besides Witelo's was a "Book on Weights" by Jordanus Nemorarius earlier in the century. In this work he is said to have made progress in dynamics beyond the ancients. Another invention of great use to science, clocks, was worked out during the middle ages. An innovation of great convenience in scientific reckoning and records was made when Leonardo, a merchant of Pisa, in a work written first in 1202 and then revised in 1228, brought the so-called Arabic numerals to the attention of Western Europe. Some progress in algebra was also made in the middle ages, and Roger Bacon emphasized the importance of mathematical method in scientific investigation.

It can not be shown that Roger Bacon actually anticipated any of our modern inventions, but the following passage from one of his works does indicate that an interest existed then in machinery and mechanical devices, and that men were already beginning to struggle with the problems which have recently been solved.

Machines for navigation can be made without rowers so that the largest ships on rivers or seas will be moved by a single man in charge with greater velocity than if they were full of men. Also cars can be made so that without animals they will move with unbelievable rapidity; such we opine were the scythe-bearing chariots with which the men of old fought. Also flying machines can be constructed so that a man sits in the midst of the machine revolving some engine by which artificial wings are made to beat the air like a flying bird. Also a machine small in size for raising or lowering enormous weights, than which nothing is more useful in emergencies. For by a machine three fingers high and wide and of less size a man could free himself and his friends from all danger of prison and rise and descend. Also a machine can easily be made by which one man can draw a thousand to himself by violence against their wills, and attract other things in like manner. Also machines can be made for walking in the sea and rivers, even to the bottom without danger. For Alexander the Great employed such, that he might see the secrets of the deep, as Ethicus the astronomer tells. These machines were made in antiquity and they have certainly been made in our times, except possibly a flying machine which I have not seen nor do I know any one who has, but I know an expert who has thought out the way to make one. And such things can be made almost without limit, for instance, bridges across rivers without piers or other supports, and mechanisms, and unheard of engines.

Since Bacon's authority concerning Alexander is unreliable and his conjecture concerning ancient scythe-bearing chariots unwarranted, we may also doubt if steamboats and automobiles had "certainly been made" in his day; but there seems little doubt that men were trying to accomplish such things.

The modern science of geology was a sealed book both to the middle ages and to antiquity. But in geography the middle ages seem to have preserved the knowledge of the ancients and to have added considerably thereto. The north of Europe and its adjacent seas now became better known. In the thirteenth century medieval missionaries and travelers penetrated to the far East, and the accounts of the Venetian trader, Marco Polo, and of the Franciscan friar, William of Rubruk, gave information concerning China and Japan,—lands practically unknown to the men of classical times. The mariner's compass must have been known in western Europe by the twelfth century; it is first mentioned by Alexander Neckam, the same man who thought that Adam's fall caused the spots on the moon. It very possibly was a western invention, since it can hardly be proved that it was known before this in the Orient, where some think that it was first introduced by the Portuguese. After Neckam the compass is frequently referred to by western writers and was evidently in common use. The old story that sailors were long afraid to use the new instrument lest they be accused of magic seems to be an arrant fabrication with no foundation in the writings of the time, which speak of the invention in a tone of perfect freedom and unconcern. In the fourteenth century came the development of deep sea sailing and Atlantic navigation; and the Portuguese by 1350 had discovered the Canary, Madeira and Azores Islands. The Italian sailors became so expert in charting coasts that Professor Beazley affirms that a certain fourteenth-century map of the Mediterranean is superior to any other until as late as the eighteenth century. Thus in the middle ages the foundations were laid for the circumnavigation of Africa and discovery of America in the last decade of the fifteenth century. Already in Dante's time every well-educated person knew that the world was round and that the people on the other side could not possibly fall off; and any one who read Pliny and Seneca, as every medieval student of nature did, could read, as Roger Bacon did, that the space dividing the west of Spain from the east of India was not great. Other authorities, however, made the distance much greater.

Alchemy, the art which strove to convert metals of less value into gold, is usually associated especially with the middle ages, and regarded as a proof of their superstition compared to the scientific perfection of modern chemistry. We must make several amendments to this view. First, alchemy is in no sense peculiarly medieval but existed in the ancient Greek-speaking world and perhaps came down from ancient Egypt.

Berthelot found 160 tracts by Greek alchemists. Also, various distinguished scientists continued to believe in the transmutation of metals as late as the seventeenth century. Second, thirteenth century alchemy was less superstitious and more scientific than in previous periods, whether among the Greeks or more recently among the Arabs. This fact has been rather obscured because the editors and publishers of books on alchemy in the sixteenth century preferred to print such treatises as made great pretensions and were full of mystic language. Thus the productions of charlatans got into print and the more sober works of rational investigators remained for the most part neglected in manuscripts. These, however, have now been studied by Berthelot with the following results.

Whereas Greek tracts on alchemy are all in an archaic enigmatic style, "combining in one undecipherable medley terms of obscure meaning, magical formulas, astrological notions, citations from mystic authors, and cryptic allusions to a philosophy long since buried too deep for present resurrection"; on the contrary, the thirteenth century treatises are full of positive details and rational argument. Moreover, the medieval alchemists are careful to refute those who deny the possibility of transmuting metals, while it does not seem to have entered the heads of the Greek alchemists that any one should doubt the truth of their art. Third, this progress is not due to the Arabs. Berthelot discovered only one treatise in Arabic which contained precise and minute details about chemical substances and operations. As a rule the Arabian alchemists wrote "theoretical works full of allegories and declamations." For a long time several works important in the history of chemistry as well as of alchemy were regarded as Latin translations from the Arab Geber, who was consequently regarded as a pioneer in the history of science. Berthelot discovered the Arabic manuscripts which turned out to be of little value and largely copied from Greek sources. On the other hand, the Latin works which had gone under Geber's name were produced in the thirteenth and fourteenth centuries by men who seem, like Adelard of Bath, to have preferred to attribute their own ideas to the Arabs.

Let us examine for a moment with Berthelot the chief of these treatises. It is "a systematic work, very well arranged." "Its modest method of exposition" differs greatly from "the excessive and vague promises of the real Geber." It refutes scepticism as to alchemy in a long scholastic discussion typical of the thirteenth century. But this is no mere scholastic treatise. Parts of it possess "a truly scientific character" and show "the state of chemical knowledge and theory with a precision of thought and expression unknown to previous authors." The writer "defines carefully silver, lead and the other metals, and traces the characteristic features of their chemical history as far as it was then known. If you leave out a few incorrect details connected with trans-

mutation, all these chapters show the stamp of solid science." Elsewhere the writer describes chemical operations, and "each description is full of special details and illustrated in the manuscript by exact figures."

Roger Bacon, too, shows us that alchemy was not intent merely upon transmutation, when he defines it as the science "concerning the generation of things from the elements, and concerning all inanimate things, such as the elements and humors single and compound, ordinary stones, gems, marbles, gold and other metals, sulphurs, salts, dyes and colors, oils, bitumen and countless other things." The invention of gunpowder has sometimes been attributed to Bacon, probably incorrectly; but he mentions some explosive as already in common use in children's toy caps and torpedoes.

We have already seen that there was a good deal of scepticism about the transmutation of metals in the thirteenth century. The consensus of learned opinion was that most alchemists produced a mere appearance of gold which would not stand severe tests. However, it was believed that by reducing the metals to their constituent elements or to first matter one might then combine them anew into gold. The difficulty, of course, was in not realizing that the metals themselves were elements.

Astrology was another medieval study which, like alchemy, was partly scientific and partly superstitious. No clear distinction in meaning was observed between the words astronomy and astrology. Either one was used to include both knowledge of the movements of the heavenly bodies and prediction of the future from them. Indeed, it was largely due to this sensational and superstitious side of the subject that sober astronomical observations made so much progress in both antiquity and the middle ages. Astronomy in those days was the most advanced of any natural science, although the Copernican theory and the telescope were as yet in the future. Astronomy was classed as the chief of the liberal arts; numerous treatises concerning the heavens were composed; Ptolemy's out-of-date astronomical tables were replaced by those of King Alfonso the Wise of Spain; Roger Bacon pointed out the need of reforming the calendar which Pope Gregory accomplished centuries later; in 1344 an archbishop of Canterbury was the first to expound the correct theory of polygonal stars.

Moreover, astrology, like alchemy, became more scientific in the thirteenth century than before, and it supplied what may almost be called the fundamental scientific hypothesis of that period. The middle ages no longer regarded the planets as gods; and they did not so much emphasize the notion that the fate of this or that man can be predicted from the constellations, as they did insist that the whole world of nature on our globe was controlled by the orderly, unceasing and unchanging revolutions of the heavenly bodies. All generation and corruption in

organic life was supposed to be so controlled, and even inorganic matter was thought to receive impressions from the stars. Even the members of the human body were parceled out under the control of the different planets and signs of the zodiac. How far one thought human fate under the stars simply depended on how far one attributed human action to appetite and environment, rather than to reason, will and divine interference. In any case, astronomy and astrology must be reckoned with in botany, zoology, mineralogy and medicine; and became the supreme science, the one underlying the rest.

Furthermore, astrology was no easy art, but had a very complicated technique as well as an enormous scope. The pursuit of this intricate superstition must, like the disputations and carefully analyzed arguments of the scholastics, have exercised a beneficial effect upon the muscles of the human mind. It has always been a matter of some wonder to me that, even after astrology was proved to be false, its former devotees did not continue to urge the study of this outworn subject on the ground that it would provide good mental discipline.

Medieval medicine was connected with natural science, and sometimes with astrology; but there is not time to speak of it now except to say that there were several schools or university faculties of medicine, that numerous medical treatises have come down to us, and that, while in the main medicine was still controlled by the theories and authority of Galen, there seems to have been some progress. Surgery received a new impulse in Italy in the thirteenth century, though the epoch-making discoveries of Vesalius and Harvey were still far in the future.

We have seen that Aristotle was not the sole authority of medieval science; I wish now to emphasize that it did not rely solely upon authorities, no matter how numerous. We have already heard Adelard prefer reason to mere authority, but besides reason medieval students of nature recognized observation and experience as criteria of truth. Albertus Magnus, for instance, in the later books of his work on animals, often says, "I have tested this," or "My associates and I have experienced this," or "I have proved this is not so," or "But I have not experienced that." When discussing whales, he "passes over the writings of antiquity on this topic because they do not agree with experience," and gives his own personal observations instead. Often, indeed, he questions the reliability of former writers, drawing a sharp line between those who state what they themselves have seen or experienced and those who appear to repeat rumor or folk-lore. He will not accept everything that Pliny the Elder says in his "Natural History," and he is particularly chary of accepting the assertions of Solinus and Jorach, assuring his readers that

> those philosophers tell many lies and I think that this is one of their lies.

In his treatise on plants, too, which has been called the chief work

in botany between Theophrastus and Gesner, Albert limits himself to "those plants better known among us." Of some of these he has personal knowledge, for others he cites those writers

> who are not too ready to state anything unless it is proved by experience. For in such matters experience alone gives sure information.

Again in his "Physics" Albert states that

> a conclusion contrary to the senses is incredible; and a principle which does not agree with experimental knowledge acquired by the senses is no principle but quite the opposite.

Indeed, medieval men not merely trusted in observation and experience; they experimented. The inventions which we have mentioned involved experimentation. The efforts of the alchemists involved experimentation. We have heard Peter of Spain contrast "ancient philosophers" with "modern experimenters." Roger Bacon has been given undue credit for his discussion of "experimental science," and has been lauded as the first prophet of modern science in the wilderness of scholasticism. But his views seem to have really been the common property of his age, as I have shown more fully in an article upon "Roger Bacon and Experimental Method in the Middle Ages," which appeared in *The Philosophical Review* (May, 1914).

So far we have considered the serious side of medieval science and the progress which was then being made, slight indeed compared with the rapid strides of science in our own time, but well worth the notice of any one interested in science's first steps. But it would be unfair to stop there; if we disclose medieval science's merits, we must also draw forth its frailties and lay bare the superstition, the absurdities, the credulity which characterized the study of nature then. Fortunately this side of medieval science is as amusing as the other was serious.

The credulity of medieval men is something astounding. Roger Bacon and Albertus Magnus are both sceptical at times. Then again they simply amaze one by their incomprehensible gullibility. For instance, Bacon classifies the prophetic writings of Merlin among "reliable authorities"; he tells of a woman of Norwich who lived without food for twenty years, "as the bishop proved by a trustworthy examination"; he says that "papal letters attest" that a German captured by the Saracens received a medicine which prolonged his life to 500 years. He has "learned without deceit or doubt from men of proved faith" that "good flying dragons" still exist in Christian Europe, and that eating their flesh will prolong life and develop the mind to a high degree. Moreover, some of these assertions occur in the very midst of his discussion of experimental science. Albert is somewhat less credulous on the theme of dragons and suggests that meteors or flaming vapors may have been mistaken for flying dragons breathing fire. But Albert falls a victim to a sea-serpent yarn, having "heard from trustworthy

persons" that a serpent with the virgin countenance of a beardless man was recently killed in an island of Germany. Another "trustworthy person" told him that he saw in an eagle's nest 500 ducks, over 100 geese, about 40 hares, and many large fish, which were all required to satisfy the hunger of the young eaglets.

Besides miscellaneous instances of credulity, and the errors of alchemy and astrology already mentioned, we find medieval books on nature full of marvelous and fantastic properties attributed to plants, stones, birds and beasts. Especially wonderful powers are attributed to gems. A French Bishop Marbod in his book on stones tells us that the sapphire nourishes the body and preserves the limbs intact. One who carries it can not be injured by fraud or envy, and is impervious to fear. It sets prisoners free; and is even represented as placating God and rendering him favorable to prayers. It makes peace between foes. By means of it the future can be predicted. It cools one off and checks perspiration. Applied in a pulverized state with milk, it heals ulcers, cleans the eyes, cures headache and ills of the tongue.

But plants, too, as well as gems, have remarkable powers. The German abbess Hildegard, in her work on "The Subtleties of Diverse Creatures," mentions certain plants which fish eat, and which, if a man could procure and eat, would enable him to go without food for four or five months. Adam used to eat them now and then, after he had been cast out of Eden, but not when he could get other food, since they make one's flesh tough. As for the strange virtues possessed by birds, Hildegard tells us that mistiness is marvelously removed from the eyes by catching a nightingale before daybreak, adding a single drop of dew found on clean grass to the bird's gall, and anointing the eyebrows and lashes frequently with the mixture.

Hildegard's chapters on quadrupeds are delightfully quaint. The camel is peculiar in that its different humps possess different virtues. The hump next its neck has the virtues of the lion, the second of the leopard, the third of the horse. Unicorns can never be caught except by means of girls, for they flee from men, but stop to gase diligently at girls, because they marvel that they have human forms, yet no beards. "And," adds Hildegard,

> if there are two or three girls together, the unicorn marvels so much the more and is the more easily captured while its eyes are fixed upon them.

When a weasel is sick, another weasel digs up a certain herb and breathes on it for the space of an hour and then brings it to the sick weasel who is cured thereby. This herb is unknown to other animals and to men, and it would do them no good if they did know of it, since its own virtue is not efficacious, nor would their breathing upon it make it so. But the heart of a weasel, dried and placed with wax in the ear, benefits deafness or headache. A fine cure for epilepsy is to

put a mouse in a dish of water and then give this water to the patient to drink, not to mention washing his forehead and feet in it. As with drinking Postum instead of coffee, "There is a reason." It is this,

> Inasmuch as the mouse runs away from everything, therefore it drives away the falling disease.

Marbod and Hildegard were twelfth-century writers, and somewhat naïve and undiscriminating in their acceptance of marvels. The thirteenth-century encyclopedias and works on medicine do not contain so much chaff in proportion to their wheat; but they still contain a great deal. Even Roger Bacon, who declared false and disproved by experiment several such notions as that only goat's blood can break adamant and that hot water freezes faster than cold,—even Bacon still speaks of the "almost miraculous" powers of "herbs and stones and metals." However, the writers come to recognize that there is something peculiar and requiring explanation in these strange properties ascribed to the things of nature. In the thirteenth century they are distinguished as occult virtues and are regarded as marvelous. It is admitted that reason can not account for them, but their existence is declared to be attested by experience.

Thus Albertus Magnus admits that it is difficult to explain the strange virtues of gems, and says that many students of nature seem to doubt whether stones possess any such attributes as to cure ulcers, counteract magic potions, conciliate human hearts, and win battles. But he insists that these occult virtues are well-established facts, and gives two examples attested by his own experience, namely, the magnet's power to attract iron and a sapphire which he saw cure ulcers. Some plants, too, Albert declares, have "divine effects which students of magic especially investigate."

On the other hand, Vincent of Beauvais, while he still agrees with Marbod that the virtues of gems are so marvellous that they can be accounted for only as the result of direct divine influence, thinks that plants possess only natural powers, which are chiefly medicinal. Nor does either Albert or Vincent usually recommend fantastic or irrelevant methods of using herbs medicinally. Many, however, of the medicinal virtues which they ascribe to plants are probably false, and they also show a tendency to make each plant a panacea for a long list of very miscellaneous and unrelated diseases. This may be illustrated by a passage taken quite at random and which happens to be about the nasturtium:

> It is acid and hot and dry. It is a gentle purgative and laxative, and dries up the gases of an empty stomach. Used as a potion or liniment, it keeps one's hair from falling out. It is beneficial for abscesses and carbuncles, if taken with salt and water. . . . It is good for softening of the muscles, puri-

fies the lungs, helps asthma, heats stomach and liver, cures enlargement of the spleen,

and so forth.

To animals amusing habits and human characteristics as well as occult virtues were sometimes ascribed by the encyclopedists. Thus in describing the lion Albert devotes half his space to the noble and genial personality of the king of beasts, and to discrediting scientific scandal about the wiles of the lioness to conceal her *amours* with the leopard. Then we come to marvelous virtues. A man anointed with lion's fat puts every animal to flight. A diet of lion's flesh is good for paralytics. Garments wrapped in a lion's skin are secure from moths. If the skin of a wolf is left near the skin of a lion, the hair soon falls out from the wolf-skin. The tooth of a lion, suspended around a boy's neck before he loses his first teeth, protects him from toothache when the second teeth appear. Lion's fat should be used in unguents to remove blotches from the skin. Cancer may be cured by an application of lion's blood. Drinking some of a lion's gall cures jaundice. Eating its brain is a cure for madness.

If the encyclopedists attribute marvelous medicinal virtues to individual things, the medical treatises proper prefer elaborate concoctions. Sometimes the ingredients of these formidable mixtures might excite no surprise if administered separately, but the multiplicity and diversity of their combination seems strange indeed. Sometimes the recipes are utterly fantastic. Bernard Gordon assures us that for cure of eye-troubles "God even to these times has never vouchsafed to reveal a better remedy" than a combination in varying amounts of mountain willow, majoram, eufragia, celidonia, fennel, ginger, spikenard, pepper, gariofil, thucia, Persian gum, ass's milk, aloes wood, the gall of an eagle, a hawk and a mountain goat, balsam and honey. Of these ingredients

those that need pulverizing are to be pulverized; those that ought to be shaken well are to be well shaken; those that should be reduced to liquid form are to be liquefied. Then, if it is summer time, they should for forty days be mixed in the hot sun, and stirred daily. And if it be winter, let the mixture be prepared with cinders, where the heat is about that of a sitting hen; and let it be stirred and kept in a glass vessel, and dropped into the eyes; and it is of so great virtue that it enables decrepitude to read small letters without eye-glasses.

Thus in the midst of a superstitious recipe we get evidence of a scientific invention.

Even the experiments of medieval men were affected by this belief in occult virtues, and sometimes resembled the tricks of magic more than the scientific procedure of a modern laboratory. Roger Bacon advocates experimental science at considerable length, but he calls the following an experiment.

A sage at Paris recently cut a snake into small sections except that the skin of its belly on which it crawled was left intact; and that snake crawled as best it could to a certain herb, by touching which it was instantly made whole. Thus the performer of the experiment discovered an herb of wonderful virtue.

But Albertus Magnus has an experiment to match this. He says:

An emerald was recently seen among us, small indeed in size but marvelously beautiful. When its power was to be tested, some one suggested that if a circle was made about the toad with the emerald and then the stone was displayed to the toad, one of two things would happen. Either the stone would be broken by the gaze of the toad, if the stone was of weak virtue; or the toad would burst, if the gem was in its full natural vigor. Things were immediately arranged as suggested, and, after a moderate interval of time, during which the toad kept its eye unswervingly upon the gem, the latter began to crack like a nut and a portion of it flew from the ring. Then the toad, which hitherto had stood immovable, began to move away, as if it had just been freed from the power of the stone.

While medieval men still accept in large measure these far-fetched virtues, they have a semi-scientific theory to account for them. It is not a case of unreasoning superstition. They agree that no satisfactory physical explanation of such virtues can be given, that the varying composition of objects from the four elements is not enough to account for such powers. Vincent thinks them due to divine influence, Hildegard sometimes connects them with demons; but other writers, as Roger Bacon, Peter of Abano, and Thomas Aquinas, attribute them to the influences impressed on matter by the stars. Here again we see how important a part astrology played in medieval science.

We, however, can find an explanation which will explain both the belief in occult virtues and the belief in astrology. They are survivals from magic. The conception of occult virtues in particular objects is magical. Much sympathetic magic, too, may be found stranded on the shores of medieval science, as is seen in the reasoning why the mouse cures epilepsy, and in the eating of lion's flesh in order to grow strong. Furthermore, incantations, amulets, characters, astrological images, are occasionally found in medieval science and medicine. Sometimes their experiments seem like feats of magic.

The reason for this is that science and magic were for a long time closely connected. As anthropologists have shown, magic plays a great part in the life and thought of primitive peoples, and it is only gradually that the science and religion of civilized peoples free themselves from the old habits and instincts. True, it is one of the glories of modern science that it has freed men from superstition and mental anarchy. But science did not come down from above nor invade from without. It grew up in the very midst of superstition and mental anarchy, just as the states of modern Europe had their beginnings in feudal society. As the kings in the middle ages had to govern under feudal limitations and even by feudal means, so science for a long time

not merely was opposed by the unscientific attitude, but was itself tinged by fantastic theories and false data. Yet the scientific attitude, like the spirit of nationality, was at work in the seeming chaos; gradually it shook itself free from error, and, by the increasing application of truly scientific methods, won a similar triumph to that which the sovereign political power gained by its gradual development of governmental institutions.

This was the process going on in the twelfth and thirteenth centuries. When men still believed in demons and witches and divination from dreams, it is not surprising that they believed also in natural magic. Only a small part of nature's secrets were revealed to them; of the rest they felt that almost anything might turn out to be true. It was a time when "one vast realm of wonder spreads around." They had to struggle against a huge burden of error and superstition which Greece and Rome and the Arabs handed down to them; yet they must try to assimilate what was of value in Aristotle, Galen, Pliny, Ptolemy, and the rest. Crude naïve beginners they were in many respects. Yet they show an interest in nature and its problems; they are drawing the line between science and religion; they make some progress in mathematics, geography, physics and chemistry; they not only talk about experimental method, they actually make some inventions and discoveries of use in the future advance of science. Moreover, they themselves feel that they are making progress. They do not hesitate to disagree with their ancient authorities, when they know something better. Roger Bacon affirms that many scientific facts and truths are known in his time of which Plato and Aristotle, Hippocrates and Galen, were ignorant. The ancients, says Peter of Spain in effect, were philosophers, but we are experimenters. Magic still lingers but the march of modern science has begun.

A HISTORY OF FIJI

By Dr. ALFRED GOLDSBOROUGH MAYER

Part III

OF all established customs in Fiji the most odious was cannibalism, yet it was always tabu for women and the lower classes, and the custom was extensively practised only by the chiefs and warriors. It is possible that in Fiji it was primitively a religious rite and did not originate in time of famine, or through motives of mere revenge. Instead of an animal, they sacrificed the best they had to the gods, and as the flesh of the animal was eaten by the chiefs, so was the flesh of man. Indeed, an old myth asserts that once there was no cannibalism in Fiji, and even when it was most prevalent there was always a party opposed to it, maintaining that it caused various skin diseases. At the town of Nakelo on the Rewa river, it was tabu to eat human flesh.

We incline, however, to the belief that the Fijians were cannibals simply because they enjoyed the taste of human flesh, for I have met with no dissent to the opinion that of all meat it is the most palatable, and it is evident that the custom could not have survived a decade had mere religion prompted its continuance. The fact appears to be that, in common with other privileges, the chiefs and priests had succeeded in monopolizing its pleasures through the agency of the tabu, for among savages the priesthood is quick to defer to the desires of those in power. In prehistoric times the natives had but little animal food, apart from the fish of the reefs and the snakes of the mountains, for pigs, ducks and chickens were introduced only recently. When man attempts to live upon a vegetable diet, even though it be varied by fish, an insatiate craving for animal food comes over him, he "Kalau's," as the natives say, and it is an interesting fact that cannibalism is almost unknown among peoples whose meat-supply has always been abundant and varied. Once it be acquired, this longing for human flesh remains a temptation haunting its possessor. Well does one remember the vim of a wild Marquesan dance. It was near midnight and the flickering glare of the bonfire cut into the blackness of the surrounding forest. An old chief, standing by the embers, led the chant, while his tribesmen, with hands joined, danced furiously around him. Translated into English, the burden of their song was "I have eaten your father, your mother, your brother, now I intend to eat you! whoo!! hack!!!"—in a bestial shriek that rang back in echoes from the cliffs. Then, one by one, at unexpected times and from unforeseen recesses, the maidens of the tribe emerged from the dark aisles among the trees; their graceful bodies glistening where the fire-light glinted upon the cocoanut oil that

covered their shapely limbs. Gay flowers stood out among the riot of their flowing locks, and like elfin things they flitted with tremulous arms outstretched until they stood fully revealed in the red glare, only to flutter silently backward and vanish. In days gone by that darkness concealed from view a gruesome meal.

Basil Thomson points out the fact that in Fiji the practise increased greatly just before the coming of white men, as had that of human sacrifice among the Aztecs a few years before the arrival of Cortez. With the sudden increase in the power of the great chiefs, it began to lose its religious significance and an acknowledged appetite for cannibal meat was boastfully proclaimed. Thus Tanoa, Ra Undreundre, Tui Kilakila, and others were cannibals because they enjoyed the taste of man, but not *all* Fijians liked human flesh, even as terrapin is not enjoyed by all white men.

The most hideous features of cannibalism were the fiendish tortures, Vaka-totogana, connected with it wherein the victims were gradually dismembered and their noses, tongues, arms, or legs cooked and eaten before their eyes, pieces of their own flesh being offered to them in derision. Even if the missionaries had accomplished nothing else, their success in abolishing cannibalism would have sanctified their labors. Let nothing blind us to an appreciation of the undaunted courage and unexcelled devotion to their faith displayed by these unselfish men and women, who, actuated by high and simple motives, left homes and friends, and labored cheerfully through long years over the seemingly hopeless task of bringing the light of a happier day to the barbarians of Fiji.

People who had died a natural death were rarely or never eaten, and only those killed in battle, captured, or wrecked "with salt water in their eyes," were offered to the gods and roasted. The dead, if killed in battle and buried, they would disinter even after the tenth day when the body could not be lifted entire from the grave and was therefore torn apart and made into puddings. Every one agrees that decomposition did not deter their appetite for human flesh, any more than it impairs our own taste for game, yet all other meat was discarded by the Fijians as by us upon the least indication of dissolution.

Among old Fijian chiefs whom I knew between 1897–1899, none expressed the slightest abhorrence of cannibalism, and some were frank enough to state that were European influences removed they would at once renew the practise. To the Fijian no revenge is assuaged until you have eaten your enemy, but the deepest contempt for a fallen foe was indicated by roasting and then refusing to devour the body.

One of the best descriptions of a cannibal feast is that given by Jackson in Erskine's voyage published in 1853; and the Rev. Thomas Williams[1] in his work upon "Fiji and the Fijians" describes the rites in detail, having often observed them.

The canoes when approaching the shore would indicate that human prey was on board by striking the water at intervals with a pole. Seeing the splashes, the natives gathered in a howling mob along the shore, the women breaking into a wild, lascivious dance. The victims were seized by the arms and dragged to the temple, their captors chanting the cannibal song:

Yari au malua. Yari au malua.
Drag me gently. Drag me gently.
Oi au na saro ni nomu vanua.
For I am the champion of thy land.
Yi mudokia! Yi mudokia! Yi mudokia!
Give thanks! Give thanks! Give thanks!
Ki Dama le!
Yi! u-woa-ai-a!

Sharp-edged strips of bamboo served as knives for the butcher, and after being roasted or steamed, the flesh was eaten by means of a wooden fork, each high chief having one of these which it was tabu for any one but himself to touch.

Cannibalism was dreaded by the lower classes for they were forbidden to participate in the feasts, and were themselves most frequently the victims of these orgies. Thus when the missionaries succeeded in developing even in a rudimentary form the force of "public opinion" the practice was suppressed far more easily than had been anticipated, for it was a rite maintained by the aristocracy and the priests and had become a terrible engine of despotism.

Another institution which appears to have been practised from time immemorial in Fiji was polygamy. The great majority of Fijians were not polygamous, however, for only the highest chiefs could afford to maintain more than one wife, and even those of most exalted rank rarely had more than ten wives. There is reason to suppose that the number of women has always been less than that of men in Fiji, owing to the greater care devoted to the rearing of warriors.

A man of the middle classes rarely married before the age of twenty-five, at which time his mother chose a wife from among the daughters of his maternal uncle (his orthogamous cousins, veidavolani). One quarter of all Fijian marriages are still of this character, and they produce healthy offspring.

Men of the lowest class frequently remained bachelors throughout life, and all unmarried females of the peasantry were disposed of by the chief of the tribe. In Mbau this match-making chief was next in rank to the vunivalu, Thakombau. It is evident that Basil Thomson is right when he says that the abandonment of polygamy could have had no serious influence upon the vitality of the race, for it affected too few.

[1] Williams was by far the most assiduous and accurate observer of Fijian customs, and it is to be regretted that his manuscript was edited and "repressed" by a Mr. Rowe of London who had never visited Fiji.

It is a common mistake to assume that social anarchy is the rule in primitive communities; for the reverse is true, and savage races are the ones *par excellence* most dominated by established forms, their system of life remaining unchanged for generation after generation. This is illustrated most clearly in an interesting paper by Lord Amherst of Hackney and Basil Thomson published by the Hakluyt Society of London in 1901, which shows that, since their discovery in 1568, the customs of the Solomon islanders have remained absolutely unaltered, until crushed under the rule of white men.

Among these fixed customs of savage tribes, some are actually better than our own. Thus in Fiji prostitution was checked as effectively as any mere system could prevent it. This was accomplished by obliging all the unmarried men to sleep each night in a special house, the Mbure-ni-sa, or men's house, while the virgins were kept at home with their parents.

Indeed, the use of the Mbure-ni-sa was even extended, under certain conditions, to the married men. There were no milk-producing animals in Fiji, and the food of the natives is still so deficient in animal proteids that it can hardly afford sufficient nourishment for healthy growth until the child is nearly four years old. Accordingly, when a child was born, husband and wife separated; she going to live for a year with her mother's relatives, and he to sleep for the following two or three years in the Mbure with the unmarried men. Thus throughout the suckling period the risk of a new conception was avoided, and the full strength of the mother was preserved to nourish her infant.

Unhappily, the Europeans saw fit to break up this system, maintaining that it interfered with family life and was destructive of mutual affection. The tabu having thus been abolished, conceptions often occur within a year following the birth of a child, and the mother's milk is rendered inefficient as a means of nourishment, while at the same time the drain upon her strength is so great that the unborn child may not properly develop. Thus the new system has increased the birth-rate, but at the same time produces weak, sickly infants whose death-rate is far greater than in former times. This indeed is one of the most potent causes of the decrease of the Fijian population, especially as the married women now attempt to escape the strain of these exhausting pregnancies by resorting to abortion, a practise which has increased in recent years to the serious impairment of the vitality of the race.

Moreover, the abolition of the Mbure-ni-sa has brought about a too sudden and promiscuous commingling of the young men and women, and the commission appointed by the British government to inquire into the causes which are producing the decline of the Fijian population has decided that sexual depravity has increased since the abandon-

ment of heathenism, for licentiousness formerly kept down by the chief's club is now merely forbidden.

Seeman states that the natives were shocked when he told them that English women frequently bore children at intervals of a year apart, and upon reflection they decided this accounted for there being so many "shrimps" (small men) among Europeans.

In common with some other primitive races, the Fijians looked frankly upon those problems of sexual relations which we attempt to ignore or to cloak under a mantle of secrecy, too often pernicious to the welfare of our race. The average European is too apt to be horrified when he hears a spade called by its simplest name, and to his mind morality implies an unnatural hypocrisy respecting the physiological facts of life. He forgets that acts and words are in themselves innocent unless their *intention* be otherwise, and in many matters of this sort the missionary has unfortunately made cowards and liars of his converts, and it is undoubtedly true that the influence of civilization in the Pacific has tended to increase rather than diminish all forms of clandestine sexual depravity.

I have heard competent and unprejudiced observers state that the Fijians were fully as affectionate in heathen times as at present. Family affection fortunately springs from nature itself and is not a product of our system of life, however cultured or barbarous. One sees the naked women of Australia, whose bodies are covered with self-inflicted scars, gaze rapturously upon their children and exhibit maternal love as truly as could any European mother, and even Wilkes, who refers to the Fijians as "the most barbarous and savage race now existing upon the globe," states that he saw "engaged couples walking affectionately arm-in-arm as with us."

One of the saddest, because the most apparent change that has affected the lives of the Pacific islanders is the needless decay of their arts. War, and the ceremonies and obligations of religion once provided the major motive for the maintenance and development of varied crafts. In fact, the intent of practically every piece of decorative work was either to propitiate the gods and tribal spirits, or to frighten a real or imaginary enemy. Nor is this peculiar to savage tribes, for all the complex ornaments which adorn the yokes of horses in Naples are "evil eye" charms which have come down almost unaltered from Roman times.

The missionary soon saw that most of his so-called converts had only added the white man's god to those of their ancestors. In order, therefore, to obliterate old beliefs, he discouraged the making of all "symbols of heathenism," and, as these were displayed in almost every implement, art fell at once under the awe-inspiring ban of his displeasure.

Yet the decline of native art was to some degree inevitable even if

the missionaries had attempted to foster and preserve it, for it perished chiefly because of its inadaptability, and the absence of a market for its wares. The cheapest calico is softer and more enduring than the best of tapa, the coarsest canvas sail is superior to that woven of pandanus leaves, the beautiful adze of polished stone fails wholly when placed in competition with even the "trade hatchet."

Yet in each group there was at least some native art which, had it been cared for by the whites, might have been preserved so that in a more or less modified form it might have furnished a permanent and progressively important means of livelihood to the natives, and thus have become a means of maintaining their racial entity and self-respect.

Art was the highest expression of their intellectual life, an absorbing field for their ambition, a means of gratifying their instinct for the beautiful, and a record of their history and their conception of the universe. It meant far more to them than it does to us with our widely varied interests, and to this the European was blind when he permitted its destruction.

All over the south seas in proportion as white men have become dominant native arts have withered. Once the canoe was built of separate pieces skilfully calked and lashed together, and its outrigger was a marvel of flexibility and strength. Yet everywhere it degenerates into a crudely hollowed log, crossed by two rough sticks to which the outrigger is rigidly tied. The house, once shapely in form and carefully thatched, degenerates into a mere shack, and every carved bowl, paddle and implement becomes rude, ugly and misshapen. All care in manufacture degenerates, and in proportion does the light of their intellectual life fade out. A hopeless apathy, a listless lack of interest in all around them overcomes their dulled minds and their lives, like those of prisoners, are no longer worth the while of living, for hope can not flower within the stifle of the cold gray walls of bigotry's bastile.

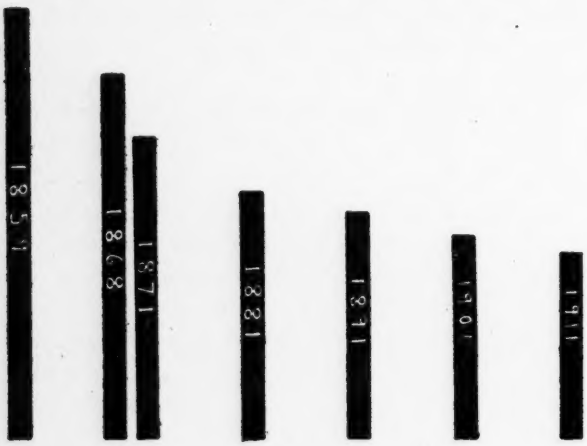
Pleasures and sports suffer as do the arts. The surf-board riders of Hawaii are now rarely seen, dances and songs are being constantly suppressed, and many happy things that once filled their minds with joy, and were beautiful in their eyes, have vanished never to be theirs again. But one resource is left to their idle minds, and clandestine immorality saps their strength. As the Government Commission in Fiji reports

> premature civilization, mental apathy and lack of ambition under the new conditions are among the most important causes of the decline of the population.

This carefully selected commission was appointed by the British government in Fiji to inquire into the causes of the decrease in the native population, and after long investigation the conclusions of the commissioners were published by the Colony in 1896.[2] It is probable

[2] Report of the Commission appointed to inquire into the causes of the de-

that in 1859 there were about 200,000 natives; in 1868, 170,000; in 1871, 140,000; in 1881 there were 114,700 and in 1891, 105,800 while in



ILLUSTRATING THE DECLINE IN THE NATIVE POPULATION OF THE FIJI ISLANDS FROM 1859 to 1911.

1901 the population had still further declined to 94,400, and the males outnumbered the females in the proportion of 8 to 7. In 1911 there were but 87,096 natives, and if the decline continues at its present rate the last Fijian must die before another century has passed.[3]

The commission decides that children have ceased to be useful, and whereas in old days they strengthened the tribe in war, they now suffer neglect. The birth rate is higher than that of England yet only 11/20 of the children survive to be one year old.[4] Another cause is said to be the general want of vitality due to the effects of past epidemics, such as the "wasting sickness" in 1797, the dysentery of 1803 and the measles of 1875. One is, however, inclined to believe that no permanent evil effects could be produced as a result of these physiological disasters. No matter how severe the epidemic, those who are physically the best are the most apt to survive and become the progenitors of successive generations, and thus the race might even be improved through natural selection. There is no evidence tending to prove that the black death

cline of the native population. Published by the Colony of Fiji, Suva, 1896, pp. v + 130.

[3] Should the natives continue to decline at the rate which has pertained since 1881 they must become extinct in the year 2004.

[4] Within recent years the medical department under the able leadership of Doctor G. W. A. Lynch has been enabled to take measures which appear to have reduced this infant mortality so that nearly 78 per cent. of the children survive the first year.

of the fourteenth century or the plague in London in the time of Charles II. resulted in any permanent physical deterioration of the races they affected. The Fijians may be a vanishing people, but in physical appearance they remain superior as of old, and their superb stature and mental attainments appear not to have declined even though the race as a whole be dying.

There is, however, one cardinal evil in the Fijian situation and that is the severe strain of child-raising which falls upon the women in a country wherein the proper food for the maintenance of lactation has not yet been produced in sufficient quantity. The children, being thus in a peculiar sense dependent upon their mothers, will be profoundly affected by any conditions which produce injury to the women of the tribe.

Yaws, dysentery and whooping cough are now primary causes of the decline of population. Among minor causes the committee mentions the abolition of polygamy; for under monogamy the mother must not only tend her child, but gather the food and cultivate the soil, whereas in polygamous days these latter duties were taken over by the other wives during the early period of the infant's life.

The report makes it clear that the decline is due chiefly to the high death rate of children, and also that we must proceed very slowly and sympathetically, using as little force as possible, in the introduction of civilization. The old socialism must gradually be replaced by a certain measure of individualism, and the warrior's ambitions must give place to those of the craftsman. Hygiene as a subject of primary importance must be taught not only in the schools, but chiefly by example, upon the plan of the college settlement, by teachers living in so far as possible as the natives themselves now live, thus *slowly* changing the habits of life of those around them, and indeed these teachers should themselves *be natives* of the most enlightened type, and maintained in government employ.

A most interesting sociological experiment has been conducted by the British in their government of the Fijians. It is one of the very few instances wherein altruism is the key-note in the rule of the strong over the weak, and its maintenance through all these years in the face of much discouragement and expense is an honor to Great Britain, in the pride of which all the world may share—it is a rare triumph of idealism over selfishness.

As Mr. Allardyce, then colonial secretary, said to me:

> We came here not as conquerors but through invitation, and the best we have to give is none too good for these people who have entrusted their destiny to our care.

Indeed, if the South Sea Islanders are now to be saved *new* interests and *new* arts must be developed by them, and new ambitions other than the withered remnants of the old must be created. Industrial schools

are sadly needed in the Pacific, and the dawn of the first real progress will appear when men like Booker Washington arise among the natives of Fiji. The establishment of non-sectarian manual training schools such as his, in so far as possible under *native* teachers and supported by *native* efforts, might soon revolutionize their whole system of life, and change them from well-behaved captives into purposeful men and women.

The missionaries now conduct nearly all the schools in Fiji, and it is much to their credit that illiteracy is almost as rare as in Germany, all the present generation being able to read and write their own language. These schools are fundamentally good, but the natives should be taught not only how to pray, but also how to labor and to live. The missionaries would doubtless welcome an opportunity to extend the scope of native education, but the expense of establishing trade schools is too great for their resources and the project demands government aid. That the return to the state would ultimately far more than repay the outlay can not be doubted, for even the non-altruistic Dutch well know the profit accruing to Java and hence to themselves through the establishment of agricultural schools for natives.

Every indication of an initiative among the Fijians in the direction of craft-development should be wisely encouraged instead of being, as at present, smothered under the cloak of a paternalism that obliterates error only by crushing endeavor.

It may be confidently hoped that the British government which has labored so persistently and at such constant expense to develop Fiji "for the Fijians" and not for the surfeit of those who would selfishly exploit the natives, will take this final step and render it possible for the natives to raise *themselves* to a position of self-dependence. This was, indeed, the confessed intention of certain high officials of the colony whom I enjoyed the pleasure of meeting when in Fiji. So consistent have the English been in their effort actually to civilize and elevate the Fijians that their policy has been pursued for years despite financial loss and the frequent protests of the whites, as is evidenced by the steady decline of the white population from 2,750 in 1871 to 2,036 in 1891, since which time it has slowly risen, becoming 3,707 in 1911. The public debt in 1910 was £104,115 and the native taxes amounted only to about £16,000, the principal source of revenue being derived from customs receipts which were £129,552, the latter being, of course, an indirect tax upon the colony itself.

Since 1874, settlers have been discouraged from employing Fijians upon their plantations, for the native population was rapidly being enslaved by the whites. In order to supply the necessary labor, Hindoo coolies from Calcutta were imported, but it seems unfortunate that these usually remained in Fiji after the expiration of their terms of service and there are now 40,300 in the group. They are a clannish,

industrious, bigoted race whom the Fijians despise and with whom they do not mingle. Indeed, there are far more half-breds between the whites and Fijians than between Fijians and Hindoos.

Although all native arts have suffered and some have wholly disappeared in Fiji, the introduction of European methods has been slower in this group than elsewhere in the Pacific. Spears and clubs and other implements of war are no longer made unless, indeed, it be to sell to tourists, and the dancing masks and wigs of former days have disappeared, along with the cannibal forks. Once the natives took great pride in their war-clubs, and a man's rank was indicated by the fashion of his club and his manner of carrying it, only chiefs being permitted to bear it over the shoulder as we would a gun. The handle was notched whenever the club had served to kill a man, and such a weapon was called a "ngandro" to distinguish it from common clubs. Indeed the more famous clubs were given individual names, a certain chief being the proud possessor of one called "the giver of rest." Elaborately carved, and built up, spears of iron-wood ten or fifteen feet long were common, and were sometimes tipped with the spine of the sting-ray, which upon breaking within the wound caused certain death. In the distant villages among the mountains of the large islands, spears and clubs were still to be seen in the houses in 1899, but from more accessible places they have long since disappeared to crowd the shelves of our museums. Everywhere the natives of the coasts have yielded, and more or less conformed to the white man's customs, but only a few miles inland, isolated by the dense forests or walled in by mountains, they were in 1900 almost as in heathen times. Yet even in these remote places the natives are not wholly separated from the world, for news is carried rapidly by word of mouth, and Wilkes speaks of a case in which a message was transmitted 20 miles through a forested country in less than six hours.

The pursuit of war was once the chief concern of the Fijians, and was often conducted in a very ceremonious fashion. An offended chief thrust sticks into the ground, and removed them only when appeased. If war was determined upon a herald was sent to the village of the enemy to announce the fact. As is universal with primitive people, the mustering of the army was the occasion for much extravagant boasting, and their faces were painted red or half red and half black. Miss Gordon Cumming gives a striking description of the wild war-dance and the boasts of the warriors who assembled at the call of Sir Arthur Gordon to take part in the war against the cannibal tribes of the Singatoka River in the mountains. "This is only a musket" cried one warrior "but *I* carry it." By contrast the men from Mbau came up in stately fashion, their spokesman saying "This is Mbau, that is enough."

The towns were often fortified with wooden stockades or stone

walls, and were sometimes surrounded by moats. There are no records of protracted sieges, for the attacking party never could carry sufficient food to enable them to remain long before the walls of the besieged. They depended almost wholly upon treachery, ambushes or sudden and unexpected assaults; and to kill a woman or a child or even a pig was considered a creditable feat, as when Thakombau's warriors returned to Mbau boasting, "We have killed seven of the enemy's pigs and two women." Before the introduction of firearms, it is probable that native warfare caused but little loss of life, for fear kept the combatants skulking at a fairly safe distance from one another.

Wilkes, who himself made war upon the natives of Malolo after they had killed Lieutenant Underwood and Midshipman Henry, describes their martial customs at great length and should be read by those interested in the matter.

The cruelties practised when a town was overcome were unspeakable, and on the island of Wakaia the chief and all within his village threw themselves over a high cliff to be dashed to death rather than surrender.

Fijian warfare, like that of cannibalism, is indeed a sordid subject. Not a single struggle waged by any tribe was for the establishment of a worthy principle. Lust for murder, the capture of women, revenge for real, or more often imaginary, insults were the actuating motives of all native wars. There is in the language no word expressing disapprobation for the killing of a human being. Indeed, no matter how brutal, treacherous or cowardly the murder of man, woman or child the murderer immediately gained the proud title of koroi, which insured to him a good position among the spirits of the world to come, and permitted him to blacken his face and chest with a peculiar war-paint. Murder was thus an open sesame to social distinction and religious well-being.

The Fijians are courageous in the sense that all men are brave when wrought up to the point of action, and when facing a situation they understand. Their first sight of a horse, however, drove even the doughtiest warriors to take refuge in the trees, and when upon a dark night Wilkes came to anchor off the coast and set off rockets, the silence of the shore broke into a long shriek of terror, village after village catching the contagion of the fright. Even to-day the white man inspires a mysterious lurking fear, and in the mountain villages and in parts rarely visited by Europeans, the women and little children shrink and run at your approach, and even the men seem somewhat "stage struck." To their minds we must be past masters of witchcraft.

Indeed, in common with all beliefs and practises which may be securely hidden from the eyes of Europeans, witchcraft still survives in Fiji, as it does among the lower classes of Europe and America. The natives are fond of the "occult" and several miracles are still per-

formed. Thus at the village of Nandawa, on Koro island, an old man stands upon a high rock and calls to the sea-turtles, shouting in Fijian, Come! Come! We are tired of waiting! upon which several turtles appear swimming toward the shore. It is highly probable that these are regularly fed and are thus always ready for the "miracle" when strangers visit the town. Koro, by the way, is the island to which the souls of all dead pigs were supposed to go to their valhalla.

At the village of Rukua on Mbenga a curious miracle play is enacted. Near the town there is a circular pit about twenty feet in diameter, the bottom of which is lined with brown-colored volcanic stones, a ring of large flat ones lying near the edge around the bottom of the depression. The pit is filled with dry sticks and a fire is maintained until the stones are red hot. Then the embers are brushed away, and out of the forest there comes a procession of young men gaily adorned with garlands of flowers and well polished with cocoanut oil. They chant as they tread slowly and deliberately over the hot stones, and then vanish into the woods, apparently uninjured; upon which pigs and vegetables are placed upon the stones and are covered with leaves and earth, and a thoroughly cooked feast is soon ready for both guests and performers. Professor Langley witnessed a similar exhibition in the Society Islands, and discovered that the radiation from the surface of the volcanic stones is very great, while the stones themselves are poor conductors of heat, thus the surface soon cools while enough heat still remains within to serve in cooking the feast. The natives can not be induced to walk over limestone, which is a good conductor and poor radiator, the surface thus remaining hot. However, the great thickness of the skin upon the sole of their unshod feet accounts in some measure for their ability to perform this "miracle." In all respects natural sole leather is superior to that provided by the "leather trust."

A pleasing art which still survives, but is doomed to extinction, is the making and decorating of tapa, or *masi,* as it is called in Fiji, where it is still used for screens in houses, and for various decorative purposes. Women alone take part in the manufacture of tapa. They carefully cultivate the paper mulberry (*Broussonetia papyrifera*), and, when about six feet high, the young trees are cut down, and the bark peeled off and soaked in water. The outer skin is then scraped off with a sharp-edged shell, and the soft fibrous inner bark is ready for beating, although it may be kept indefinitely before this process is begun. For beating, the strips of bark must be thoroughly water-soaked and soft, and two are placed one over the other upon a flattened log and beaten with a rectangular mallet, *iki,* having three of its flat sides grooved and one plane. Each pair of strips of an inch in original width may thus be beaten out into a thin sheet of felted fibers nine inches wide, although the length is reduced. Separate sheets are then welded together by beating, the overlapping edges being first glued with a paste made from arrowroot boiled in water, this welding being so cleverly done that it is

almost impossible to tell where the pieces overlie one another. The sheet is then spread upon the grass and exposed to the sun to bleach. These sheets may be very large, one we measured being 160 feet long and 12 feet wide, but Williams mentions a sheet 180 yards long!

After being bleached, they produce a pattern upon the tapa with a brown dye derived from the *Aleurites triloba,* the dull color of which is relieved at intervals by large black circular spots, thus by contrast giving a bright and effective pattern. This process of decorating is described in detail by Thomas Williams in his most interesting work upon "Fiji and the Fijians." Strips of bamboo are placed in the form of the design upon a flat surface, or the design is carved in relief in a board. Then the tapa is stretched over the template and the cloth rubbed with the dye, whereupon the color adheres to all raised places and fails to appear in the hollows, and a "printed" pattern is produced. So characteristic are the checquered patterns of the tapas of the several islands that the locality of each piece can be determined upon the most casual inspection. The black and white tapas of Taviuni are most effective, and those of Lakemba probably the most artistic made in the group. It seems strange that although these tapas have for ages been printed in designs, little or no meaning was associated with the details of the pattern. There were, however, certain appropriate patterns for weddings and other ceremonies, and the flags of the various classes of warriors were more or less distinctive. Thus at Rewa the banner of the king's or high chief's party was white with four or five vertical black stripes at one end, that of the vunivalu or general had horizontal stripes, and that of the land owners was plain white. Yet the tapa flags never became tribal emblems, on the one hand, or personal coats-of-arms, on the other, but remained merely class badges, and thus no precise symbolism was associated with the designs.

In groups other than Fiji the inner bark of the bread-fruit tree, and of the yellow hibiscus *Paritium tiliaceum* are used in making tapa. Yellow turmeric, bone charcoal, brilliant red and rich brown dyes, are displayed upon tapas of the Pacific.

The art must surely disappear, for Manchester is now printing calicos in the patterns of the native tapas and these are being sold to the islanders, who prefer them to designs of their own making. In some groups traders have brought in anilin dyes which the natives call "missionary colors," the word "missionary" being applied to almost any newly introduced thing. Thus is an ancient and primitive art being debased, and another means of employment must disappear from native life. At the time of the author's visits the beating of the *ikis* (mallets) was the most characteristic sound in a Fijian village, but in a few more years this too must go the way of many another activity which once engrossed the attention and stimulated the imagination of the natives.

Tapa in Fiji was once used for the white turbans of the chiefs and the simple waist band or *malo* worn by all men. In the case of chiefs

the ends of the waist cloth formed long streamers, those of king Tanoa being so long that they trailed upon the ground. When yaqona was served, all chiefs removed their turbans, excepting only the Roko Tui of Mbau who was regarded as being a human personification of a god.

The women never wore tapa, but were clothed in the simple *liku* or waist band of hibiscus bark or grasses which is still worn among the mountain tribes, although along the coast the Europeans have abolished both it and the *malo*, obliging all to wear a waist-cloth of calico. In some respects they were a modest people before these changes were effected, and fortunately for the natives their new rulers did not oblige them to don more clothing. In other parts of the Pacific the missionaries have forced the natives to wear European garments, far too hot for tropical climates. Such clothes are so expensive that few or none of the natives can afford to own more than one suit, and this soon becomes a filthy menace to health. Tuberculosis stalks in when European clothes appear, and all unprejudiced observers will agree that the most diseased and immoral races now in the Pacific are those who have been obliged to wear the most clothing.

Their own clothes permitted the natives to bathe freely, but the whites now demand that the natives shall don special bathing suits or at least enter the water clothed in some European garments. This practically forces them either to abstain from their health-giving sport of former times or to swim fully clothed, as they now do in Hawaii. These cold wet clothes are a cause of influenza leading to tuberculosis, and everywhere the natives are less cleanly as Christians than they were as heathens.

In former times the Fijians took great pride in the arrangement of their hair, and a wide range of individual taste was permitted in this respect, as may be seen in the illustrations given by Williams in his "Fiji and the Fijians," or the colored plate published in the narrative of the voyage of the *Challenger*. Usually they trained the hair to grow into a huge thick mop standing out on all sides fully eight inches from the head, and sometimes as much as 62 inches in circumference. In order to effect this, the hair was saturated with oil mixed with charcoal and then dyed so that blue, white, brilliant red, black or parti-colored mops were in fashion. The high chiefs had barbers whose sole duty was to care for the hair of their masters, and whose hands were tabu from feeding themselves so that others had to provide them with food and drink. Such a barber might not remove a cigarette from his mouth or hold it in his hands and was thus obliged to twist a twig around it in order to avoid the weed's coming in contact with his hands. Curiously enough, barbers might work in their gardens, but were not permitted to use their hands in eating their own vegetables. Probably no savage race devoted more care to hair and beards than did the Fijians. They are very rarely bald, and indeed this was considered to

be a great disfigurement, and the defect was concealed by a wig. To preserve these unwieldy mops of hair, the natives were obliged to sleep upon a wooden pillow which was placed under the neck and held the head four or five inches above the floor.

To the European, all customs are apt to be classed as "bad" in proportion as they *differ* from those of his own race, but it should be said that in Fiji the missionaries have been more conservative and displayed far more sympathy and sense in their reforms than elsewhere in the Pacific. Nevertheless, all forms of really active exercises or keen enjoyment have a somewhat wicked appearance to a certain type of religious mind, and unhappily the mediocre man is the one who is apt to rule in deciding the fate of such affairs. They too often fail to see that when an old custom is to be abolished *something* should be devised to take its place. Thus their vandalism of bigotry has resulted in destroying or hindering the open practise of nearly all the old arts and amusements; and almost nothing but hymns and prayers and a cheerless sabbath resembling that of Puritan days in old New England have been given to the natives in exchange for all they have been forced to surrender.

The Fijians once took great delight in their club dances, but these have now been repressed and have lost much of their former animation. In one of these festivities which we witnessed the men leaped frantically in perfect unison, branishing their clubs and throwing them from hand to hand, often shielding their eyes with one hand as if searching for a hidden or distant enemy. At regular intervals they shouted *Wa hoo!* in a fierce yell that could have been heard at a distance of a quarter of a mile, while all the village crowded in a square around the dancers, beating log drums, clapping hands and chanting something which sounded like "Somo seri rangi tu Somo seri somo," over and over again. Often the meanings of words used in their songs are unknown to the natives of modern times. Wilkes gives an excellent description of a club-dance in which the best dancers were mimicked by a clown covered from head to foot with green and dried leaves, and wearing a mask half orange and half black.

The milder mekes (songs with gestures) are wisely encouraged by the missionaries, and these are still a source of constant amusement to the natives. Fiji has not yet been suppressed into a realm of sullen silence as have too many parts of the Pacific.

There is a fascination in the elemental force of the word-pictures in these songs. We stifle in the heavy air of the dull and ominous calm. Then comes the rising roar of the onrush and our hearts go out to the frail canoes struggling so bravely in a maddened sea, and the pathos of life and death is there when the hot sun glares down once more, and the ripples glint unheedingly around the silent floating thing over which the sea-birds scream.

(*To be continued.*)

THE PROGRESS OF SCIENCE

THE SCIENTIFIC MONTHLY AND THE POPULAR SCIENCE MONTHLY

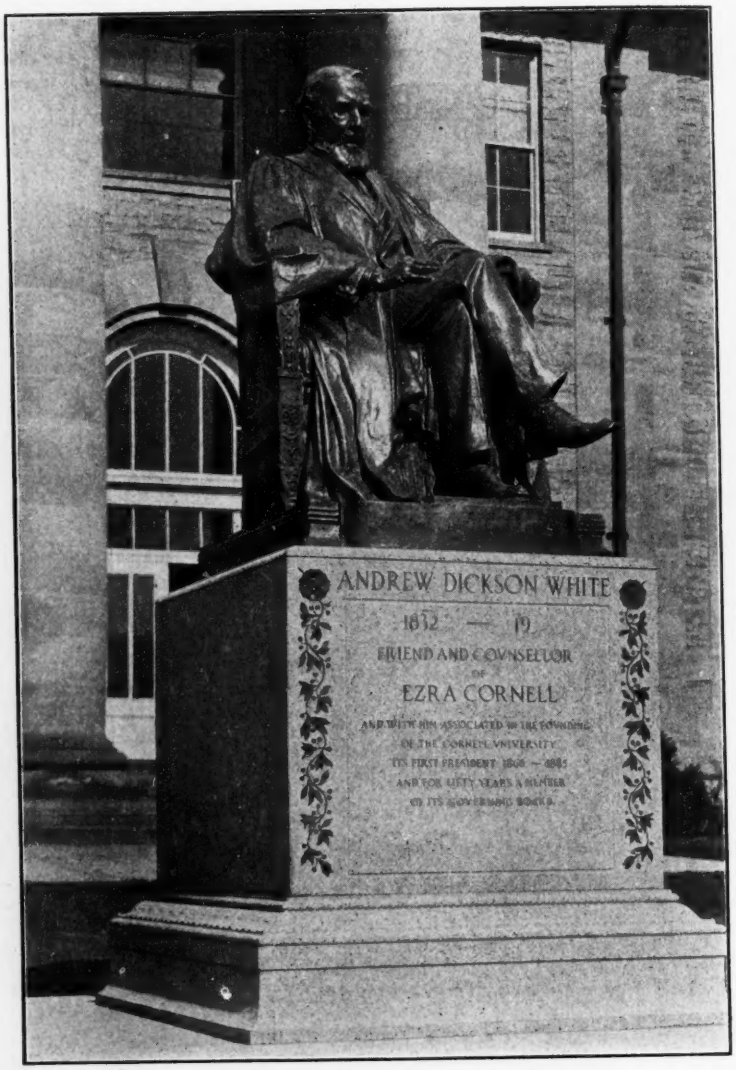
THE POPULAR SCIENCE MONTHLY, since its establishment in 1872 by J. W. Youmans and the firm of D. Appleton and Company, has endeavored to perform two functions which are somewhat distinct. On the one hand, it has aimed to popularize science, and, on the other hand, to publish articles reviewing scientific progress and advocating scientific, educational and social reforms. The objects are both important, but as science grows in complexity it becomes increasingly difficult to unite them in the same journal.

In the earlier years of THE POPULAR SCIENCE MONTHLY the doctrine of evolution excited controversy and wide public interest; it was possible to print articles by men such as Darwin, Spencer, Huxley and Tyndall, which were popular and at the same time authoritative contributions to scientific progress. Dr. Youmans had the fervent faith and missionary spirit which enabled him to conduct a journal to which the word "popular" was properly applied. At that time other magazines, such as *The Atlantic* and *Scribner's* also published articles and had departments concerned with popular science.

The last third of the nineteenth century may properly be characterized as the era of science, so rapid was the progress of science and so important the part it assumed in our civilization. This progress not only requires specialization of work, but even makes it difficult for the worker in one field to understand the work accomplished in other fields, though the barrier is perhaps due to the terminology rather than to the ideas. For the general public the difficulties are greater, and there is danger lest it may lose touch with the advances of science. But in a democracy in which science must depend on the people for support and for recruits, it is essential that a sympathetic understanding be maintained. For this purpose two journals are needed rather than one, for it is necessary to address those having different interests.

During the fifteen years since 1900, the editor of THE POPULAR SCIENCE MONTHLY aimed to conduct a journal maintaining high scientific standards and discussing authoritatively problems of scientific importance. The journal was popular, in the sense that it was not special or technical and could be understood by those having education and intelligence, but it was not popular in the sense that it appealed to all people and might number its subscribers by the hundreds of thousands. Manuscripts were received in large numbers which were clearly intended for a magazine of different type, and such a magazine is needed. A well-illustrated magazine devoted to the popularization of science should have a wide circulation and be conducted on different lines from a journal concerned with the less elementary aspects of scientific work, just as a high school and the graduate school of a university differ in their methods and in their appeal.

A group of men desiring a journal to which the name THE POPULAR SCIENCE MONTHLY will exactly apply, this publication has been transferred to them, while, beginning in October, a journal on the present lines of THE POPULAR SCIENCE MONTHLY will be conducted under the more fitting name of THE SCIENTIFIC MONTHLY. This differentiation of THE POPULAR SCI-



Statue of Andrew Dickson White by Karl Bitter,

recently unveiled on the campus of Cornell University. Dr. White, distinguished for his contributions to education, diplomacy, letters and science, contributed his chapters on the warfare of science and religion to The Popular Science Monthly.

ENCE MONTHLY into two journals is in the natural course of evolution, each journal being able to adapt itself to its environment more advantageously than is possible for a single journal. Each can perform an important service for the diffusion and advancement of science.

SCIENTIFIC JOURNALS AND THE PUBLIC

IN a democracy, journals and a newspaper press fit to educate people of all sorts to an interest in science and to an appreciation of its measureless value for national and human welfare are matters of the utmost importance. Under an aristocratic régime, science, like arts and letters, must be cultivated and patronized from above. In Germany the imperial government has directed and subsidized its schools, universities and research institutions and has aided commercial enterprises based on applied science. In England men of wealth have devoted themselves to scientific research, as they have served without payment as county magistrates and members of parliament. In both countries and in France titles and social position have been used as rewards.

Scientific research can not be undertaken as a profession. In the existing organization of society any service to an individual or to a group of individuals is paid for by them, but service to society is usually not paid for at all. If newspaper publishers, ammunition makers or army officers succeed in causing war they profit; if they advocate and maintain peace they suffer. If lawyers reduce legal complexities and delays, or if physicians decrease the causes of disease, they sacrifice their material interests. If a surgeon performs an operation for cancer he may be paid a thousand dollars for an hour's work; if he discovers an improved technique he may profit somewhat, but scarcely more than other surgeons and far less than the patients; if he should discover a cure for cancer he would receive no money reward; on the contrary, he and other surgeons would in so far lose their means of supporting their families.

So scientific research, of greater value than any other service to society, is not paid for directly. It has been mainly carried forward in this country by men employed to teach in colleges and universities who, as amateurs, give part of their time to it. In recent years the national government, endowed institutions and industrial establishments have undertaken to advance research on a business basis and the gain has been very great. But in order to maintain and increase the work under democratic control people must be taught to value it, and for this purpose the proper treatment of science in magazines and newspapers is more important than any other agency.

The problem is very difficult. One does not expect a high school, a university or a museum to be self-supporting. Even secondary schools for the children of the rich are endowed. If the American Museum of Natural History charged an entrance fee it would be an empty place; the fees for a year would not support the institution for a month. On the other hand, the side shows of a circus may be profitable. Science is so commonly ill-treated in popular magazines and newspapers that the very words "popular science" need to be redeemed. The sensational newspapers, the side shows of the circus and the "movies" supply what people will pay for. It is no discredit to our democracy that these are what they want; on the contrary, it represents a great advance when a hundred million people care for such things. We may be satisfied if progress is made by education and an improved environment in a hundred years if a slightly better germplasm is established in a thousand years.

The corporation of D. Appleton and Company were losing ten thousand dollars a year on THE POPULAR SCIENCE MONTHLY when they decided that they were not justified in continuing it. It was worth that much and far more to

the people, just as the American Museum of Natural History is worth three hundred thousand dollars a year and Columbia University is worth four million dollars a year. But a private corporation can not be expected to subscribe indefinitely ten thousand dollars a year for the benefit of the public. The weekly journal *Science* was in like manner supported for a time by Dr. A. Graham Bell and Mr. Gardiner G. Hubbard, at a total expense of about eighty thousand dollars. There are over a hundred journals and proceedings devoted to the publication of research work in America not one of which pays its expenses on a regular business basis. Magazines connected with applied science and popular mechanics may do so. This represents a step in advance, which we may hope indicates that ultimately there may be a general interest in other and more fundamental departments of science.

It would probably be undesirable for scientific journals to be directly subsidized or endowed. Indirectly they are now subsidized by the work of contributors and editors supported by endowed or tax-supported institutions and by subscriptions from public libraries. In so far as they require additional support, it can probably best come through an increase in the number of public libraries subscribing for such journals and by an increase of subscribers among those who may realize the importance of supporting an institution essential to society and its betterment.

SCIENCE AND NATIONAL WELFARE

ONE of the alleviating circumstances in the disaster of this war is the fact that it thrusts on the attention of all the place that science holds in national and international affairs. Science does not necessarily or at once make us moral or wise, although its general influence is in this direction. Human nature can not be greatly altered by a change in the environment effective for a short period and on some individuals. But when the new conditions become general and individuals are favored who fit into them, so that an altered race is preserved by natural selection, science will make our morality and enforce its observance. We may look forward to the

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FIELD RAILWAY USED IN THE GERMAN ADVANCE IN RUSSIA. Within a week of the capture of Warsaw an express railway service has been established between Lille and Warsaw.

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THE SO-CALLED "LIQUID FIRE" USED BY THE GERMANS IN REPULSING ATTACKS.

time when war will be no part of this morality and will no longer exist.

Those who can not understand or do not accept the argument that science will ultimately control human conduct must be convinced by the brute argument of accomplished fact that science is essential to national efficiency. Germany, against superior numbers, advances its lines in Poland and Russia and holds them in Flanders and France, it adjusts the nation to be self-supporting and self-sufficient, because it has a better organization of science than the other nations. Germany did not spend so much *per capita* on its army and navy as Great Britain or France, but it spent more on science and regarded science more highly. It has been stated that the British government at present employs 17 chemists, the German government about 1,000. We hear it said that Germany has developed an efficient military machine by subordinating the individual to discipline from above. It is not less true that the German university has been one of the most anarchic of institutions—both students and professors having had freedom greater than they have in American universities—and at the present moment Germany owes more to its universities as they have been conducted in the past than to its army as it is now organized.

A complicated machine is not useful in order to meet an emergency, but rather the scientific attitude and the scientific training which can react to the new situation. A superdreadnaught

built at a cost of $15,000,000 may be an asset or a burden. An equal sum spent in selecting and educating 3,000 scientific men would nearly double the number of men the country competent to advance science. The dreadnaught is a continual expense, it depreciates at the rate of a million dollars a year, its existence tends to exert an influence toward a war of aggression. The three thousand scientific men would add to the wealth of the country in peace, to its strength in a war of defense. If two years ago the officers of the German army had been put on the ships of the British navy and the ships had been sunk in the Atlantic, it would have been for the welfare of the world. If the number of men engaged in scientific research and in the applications of science could be doubled, the gain would be incalculable.

If we wish to make the nation strong in defense we should care for our children and our schools, for our scientific men and our universities—in this particular number of THE POPULAR SCIENCE MONTHLY it may be permitted to add—for our journals devoted to the diffusion and advancement of science.

SCIENTIFIC ITEMS

WE record with regret the death of Frederick Ward Putnam, the distinguished anthropologist of Harvard University; of Dr. John Ulric Nef, head of the department of chemistry of the University of Chicago, and of Dr. Joseph Austin Holmes, director of the U. S. Bureau of Mines.

THE American Association for the Advancement of Science held a successful meeting at San Francisco, Berkeley, and Stanford University, during the first week of August. The address of the president, Dr. W. W. Campbell, director of the Lick Observatory, which was printed in the issue of *Science* for August 20, is entitled "Science and Civilization."

A MARBLE chair is to be placed in the open-air Greek Theater of the University of California in honor of Eugene Waldemar Hilgard, professor of agriculture and dean of the College of Agriculture from 1875 to 1906, and now professor emeritus.—Professor R. A. Millikan, of the department of physics, has been elected president of the University of Chicago Chapter of Phi Beta Kappa.

DR. WILLIAM H. WELCH, professor of pathology in the Johns Hopkins University, and Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, have sailed for China where they go on behalf of the China Medical Board of the Rockefeller Foundation to report on the medical schools and hospitals.—The schooner *George B. Cluett*, chartered by the Crocker Land relief expedition to go in quest of Donald B. MacMillan and the members of his party in Greenland, has sailed from North Sydney, Nova Scotia. Dr. Edmund Otis Hovey, of the American Museum of Natural History, chairman of the Crocker Land Exploration Committee, is in charge.

GOVERNOR DUNNE has signed the bill giving $5,000,000 to the University of Illinois for the biennium. It is the largest grant made in a single law to any university in the United States.

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